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The Genus *Notonecta* of the World

(Notonectidæ-Hemiptera)

H. B. HUNGERFORD,

Head of Department of Entomology, University of Kansas, Lawrence.*

CONTENTS

ABSTRACT: This paper is the result of studies covering a number of years and visitations to many important museums of Europe and North America. All species are redescribed and most of them are illustrated in color. Besides five color plates there are twelve plates in black and white, illustrating structural parts of taxonomic interest. Keys to the species of each hemisphere are included.

* Contribution from the Department of Entomology, University of Kansas with acknowledgments to the University of Michigan Biological Station for opportunity to pursue this study during several summers there.

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INTRODUCTION

IT IS now twenty-nine years since the appearance of G. W. Kirkaldy's [47] "Uber Notonectiden," which concluded his studies on the Notonectidæ of the world, and thirty-six years since his "Revision of the Notonectidæ, Part I," [45] was published. It was in this last-named paper that Doctor Kirkaldy reported his studies upon the genus Notonecta. In the years that have intervened between that time and the present some species have been described as new and structural characters of specific value discovered that are much more precise than those known to him. I believe, therefore, that it is time to assemble our knowledge of this genus, and, if possible, stimulate a wider interest in this group. Surely there are species not yet taken or recognized as new, and more intensive collecting and closer scrutiny will prove fruitful indeed. There are vast areas where the terrestrial insect fauna is quite well known from which the aquatic collections are very meager. This is due in large measure to the fact that the equipment necessary for thorough water collecting is somewhat different from that employed in the capture of terrestrial insects. While much interesting material could be taken with the ordinary land nets, collectors are loath to dampen their equipment. A little more attention to water insects by the general collector would be amply repaid.

In passing in review the literature that has dealt with the Notonecta of the world we find just two papers of length—Fieber's "Rhynchotographieen," [30] 1851, and Kirkaldy's "Revision of the Notonectidæ," [45] 1897. These papers were preceded by the following, which paved the way: Linnæus in his tenth edition of "Systema Naturæ," 1758, erected the genus Notonecta and placed in it three species, *N. glauca, N. striata* and *N. minutissima*. The last two were later removed to other genera. Leach in his "Classification of Notonectides," [51] 1817, proposed a new genus Plea, and Spinola in his Essai,[79] in 1837, brought out the genera *Anisops* and *Enithares*.

In Fieber's paper a number of new species were described and many varieties proposed on the basis of size and color alone. Thus only in those cases where the types are extant can Fieber's species be fixed with satisfaction. His casual disposition of previously described species is well illustrated by his treatment of Amyot and Servilles *Notonecta mexicana*. After describing *N. klugii* he remarks that *N. mexicana* "dürfte wohl nur eine varietät der oben beschriebenen *N. Klugii* sein, oder zur folgenden gehören" (his own *N. impressa*). A further problem in nomenclature arises from this

author's treatment of specific names. For illustration: He describes *Notonecta variabilis* in three lines and then names and describes four varieties, citing the habitat of each; the first variety, *N. scutellaris*, from Brazil and Porto Rico, the second, *N. maculata*, from Baltimore (U. S. A.), and the third and fourth varieties from Brazil. Since two or more species are involved, it is necessary to consider his first-named variety as his *N. variabilis* and its locality as the type locality.

In Kirkaldy's paper, which appeared nearly fifty years later, the author made an honest and worthy effort to set in order the taxonomy of the genus Notonecta. He appears to have made every attempt to locate and examine types and to gather together all the material he could command. His types have been designated and preserved. He introduced some structural characters and brought some order out of the chaos. His allowance for wide variability in some species, has, in some cases, been too great, giving an unwarranted distributional range for such species. For example, he did not note the specific differences between the common North American *Notonecta undulata* Say and a much smaller species in Chile.

In this, the third general study of the genus, I have gone to the sources both for descriptions and types as far as they have been available to me. I have tried to account for every named species, but there are some descriptions without existing types or without material from type localities that fit the descriptions which are often too brief. Whether the descriptions are inaccurate, or whether the species in question have not been seen by me, I cannot say. Most of the older descriptions are based on color and it is almost impossible to appropriate them with any degree of certainty. This paper has been in progress for twelve years and publication withheld in the hope that every case might be clarified. I find that the time has come when I must present my results, such as they are, hoping that the future may uncover points now obscure to me. The colored figures so faithfully drawn for me by Miss Kathleen Doering will enable anyone to determine the specimens in the catch that are fully and typically colored. The teneral forms and the bichromatic species may be perplexing. In such cases note the size, shape of the head, thorax, mesotrochanters, abdominal sternites and genitalia. Kirkaldy [45] made a significant contribution to the taxonomy of the Notonecta when he introduced the more or less precise measurements of the head. Champion, 1901, in the Biologia Cen-

trali Americana (Hem.-Het., Vol. II) noted the fact that certain species have the ventral abdominal keel bare, while others have this keel covered with hair. Delcourt's [22] study of the biology and pigmental variations of the forms of his region have been helpful; indeed, he demonstrated the value of biological facts in establishing his *N. viridis* as a distinct species. Edwards [25] in describing his *N. halophila* (now known to be *N. viridis* Delcourt) called attention to the anterolateral angles of the prothorax.

In 1917, while studying the biology of some species of Notonecta in New York state, I discovered that the female gonapophyses have some specific characteristics.[37] A little later I[39] investigated the value of the male genital capsules and found them to be quite precise and satisfactory in specific determination. An examination of long series of a given species taken from widely separated places in the United States has demonstrated the fixed characters of the male genitalia. Since that time I have submitted drawings of the genital capsules of the species that I have described, and other workers have used the male genital characters in taxonomic problems with success.

In 1922 R. Despax [24] made a study of *Notonecta maculata* Fabr. and *Notonecta glauca* L. and figured the genitalia. In 1924 Raymond Poisson [65] figured the male claspers of *Notonecta furcata, Notonecta glauca, Notonecta maculata* and *Notonecta viridis* Delcourt and demonstrated their specific differences. He writes: ". . . les différentes pièces de l'armature génitale, dans chacune des espèces, conservant une structure constante." More recently this last author [66] has compared the three species common to his country and Asia Minor. His drawings show general resemblance in each case. Esaki (1927), in describing his *N. horvathi* (= *N. pallidula* Poisson, 1926), compared the direction and relative length of the lateral margin of the pronotum of this species with that of *N. glauca* Linn., and in his recent description of *N. saramao* Esaki he has attempted to state precisely in degrees the anterolateral angles of the pronotum.

Another character that I have found to be of value in separating certain confusing species is that of the mesotrochanter.[40] In some species, the majority, indeed, it is rounded, but in others it is angulate or even spurred. The shape of the sternites of the abdomen are often specific, and the last abdominal sternites of the females are especially useful. The characteristic shape of the head and thorax often defy a word description, yet are sufficiently distinctive to identify a species. The sexes are sometimes of different color, as,

for example, the males of *Notonecta lobata* Hungerford, which are usually black, while the females are red. They may also be of somewhat different shape. The head and thorax, for example, of Kirkaldy's *Notonecta ceres* are quite unlike in the two sexes (see Color Plate III, figures 2 and 3). The males are, in many species, slightly smaller and the distance between the eyes slightly less, relatively, than in the females. In every case of doubt an examination of the quite precise characters of the male genital capsule will settle the question of specific identity.

FAMILY CHARACTERISTICS

The Notonectidæ embrace perfectly aquatic forms differing from all others (except the Pleidæ and Helotrephidæ formerly included in this family*) in the persistent habit of swimming on their backs. They are deep-bodied, convex dorsally and more or less triangular in cross section. The eyes are large, reniform, and twice sinuated on the outer side. Ocelli are absent. Antennæ with three or four well-defined segments and partly concealed between the head and thorax. Beak four-segmented. Front and middle legs adapted for grasping and hind legs more or less flattened and fringed for swimming. Tarsi two or three segmented (counting a small basal segment). Two tarsal claws present in all, but inconspicuous on the tarsi of the hind legs. Scutellum visible. Abdominal venter with median longitudinal keel provided along the lateral margins at least with guard hairs, which, together with movable rows of similar hairs from the sides of the venter, are capable of closing over the two longitudinal troughs thus forming air chambers.

I propose to arrange the genera of the family as now restricted as indicated in the key which follows:

KEY TO GENERA OF NOTONECTIDÆ

A. Hemelytral commissure without pit at anterior end.............(Subf. NOTONECTINÆ.)
  B. Intermediate tarsus with two well-developed segments and a very small basal one. Intermediate femur stout with anteapical pointed protuberance. (Tribe NOTONECTINI.)
    C. Anterolateral margins of prothorax not foveate.................*Notonecta.*
    CC. Anterolateral margins of prothorax foveate. (See Pl. VI, fig. 2)...*Enithares.*
  BB. Intermediate tarsus with one well-developed segment and the middle femur without anteapical pointed protuberance.......................(Tribe NYCHINI.)
    C. Antenna 4 segmented..*Martarega.*
    CC. Antenna 3 segmented..*Nychia.*
AA. Hemelytral commissure with pit at anterior end.† (See Pl. VI, fig. 7.) (Subf. ANISOPINÆ.)

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* These two families forming the superfamily Pleoideæ Esaki and China are distinguished from the Notonectoideæ by having hemelytra thick and united apically. Ventral abdominal segments may be medianly tuberculate but not carinate.

† Poisson[68] 1926 considers this a sensorial organ in *Anisops producta* Fieb.

B. Ventral keel not extending onto last abdominal segment. Male genital capsule cleft behind. Males without stridulator protuberance on front tibia. Females with short gonapophyses.......................................*Paranisops.*

BB. Ventral abdominal keel extending onto last abdominal segment. Male genital capsule closed behind. Males with stridulatory protuberance on front tibia. Females with elongate subspatulate gonapophyses.

C. Male with anterior tarsus 1 segmented..........................*Anisops.*

CC. Male with anterior tarsus 2 segmented..........................*Buenoa.*

The above arrangement is new, but appears to me to be more logical than any proposed thus far. Kirkaldy,[45] 1897, divided the family into Notonectinæ and Pleinæ. Hale, 1923[32] and 1924,[33] followed Kirkaldy, as did Hutchinson,[41] 1929. Esaki and China,[28] 1928, removed Plea from the Notonectidæ and revived the family Pleidæ first erected by Fieber under the name Pleæ. They made the following disposition of the groups formerly embraced by the family Notonectidæ:

Superfamily Notonectoideæ for the family Notonectidæ.

Superfamily Pleoideæ for the families Pleidæ and Helotrephidæ.

Hutchinson,[41] 1929, proposed to divide his Notonectinæ into the tribes Notonectini and Anisopini, the first embracing Notonecta and Enithares and the second Nychia, Anisops, Buenoa, and Paranisops. He did not undertake to place Martarega B. White and Signoretiella Berg, but suggested that a third tribe might have to be instituted for them.

There seems to be no good reason for separating Nychia from Martarega. These two genera belong in the same tribe. They agree in general facies, both have eyes contiguous at base; both have the face transversally depressed; both have a curious curve in the costal margin of the hemelytra; both have male genital capsules that are cleft behind.* In every way save one they are quite alike. Nychia has a three-segmented antenna and Martarega a four-segmented antenna. However, it is conceivable that Nychia has lost the fourth segment by atrophy since it is small and loosely joined in Martarega. They are indeed closely related genera and belong in the same tribe.

Whether Enithares is closer to Notonecta than to the Nychia-Martarega group is a debatable question.† It shares some characters with one and some with the other. It is like Notonecta in having the eyes well separated, in having middle femora stout and

* Doctor Jaczewski,[42] 1928, in his "Notonectidæ from the State of Paraná," p. 132, describes the genital capsule of Martarega.

† Doctor Jaczewski,[43] in Notes on Some West-African Heteroptera," 1926, p. 78, places it with Notonecta, and I concur with him in this opinion.

equipped with an anteapical proturbance, in having the claspers of the male genital capsule in most species alike,‡ in having the same number of tarsal segments (two well-developed segments and a very small basal one in the front and middle legs).

On the other hand it has the anterolateral margins of the prothorax foveate like Nychia and the shiny surface and texture of the hemelytra. The ædeagus is unlike Notonecta.

As a matter of fact it would seem to me that a cytological study of these various genera might throw some light upon the problem. A little work has been done on Notonecta and has been of real value in understanding relationships within the genus.

In the above key the genera are arranged in phylogenetic order beginning with Notonecta, the most primitive genus, and progressing to the highest. No linear arrangement is consistent in all regards. The best one can do is to use the most fundamental differences and allow for parallel and independent modifications. For example, the ovipositors of Notonecta females may be short and weak or long and strong.

The genus Notonecta embraces 63 species, 14 subspecies, and is widespread over the earth. There is one species in Australia, one in Africa south of the Sahara, several in Asia, several in Europe and North Africa, 25 in North and Central America and 20 in South America. The genus Enithares, with a single exception (*E. brasiliensis* Spinola from S. A.) is found in the Eastern Hemisphere only. Nychia belongs to the Eastern Hemisphere and has its counterpart Martarega in South America. Anisops is widely distributed over the Eastern Hemisphere and is replaced by Buenoa in the Western Hemisphere. Paranisops is confined to Australia.

From the standpoint of distribution alone, Notonecta might be considered the oldest genus. This consideration, however, is supported by the four segmented antennæ, by the three segmented tarsi and by the lack of asymmetry in the male genitalia. Enithares, as stated above, comes next. It is the only other genus represented in both Hemispheres. Its only representative in the Western Hemisphere is a very large species which has the male genital claspers unlike. So far as I know all of the other species in the genus lack this asymmetry.

In some regards Enithares may be more primitive than Notonecta. The interocular space shows less variability than in Notonecta. The female gonapophyses are uniformly weak, and Hale[32] has reported

‡ *Enithares braziliensis* Spinola has the right and left claspers unlike. (See Pl. VIII.)

that "Enithares commonly anchors itself to submerged objects, even walking up a plant stem to the surface for a renewal of its air supply." While species of the genus Notonecta anchor themselves to submerged objects, I do not recall having seen them climb supports to the surface. Nevertheless the foveate anterolateral margins of the prothorax, the shiny surface and the beginnings of asymmetry in the male genitalia anticipate the Nychini.

Nychia and Martarega have the male claspers unlike on the two sides. In Martarega the claspers are the less differentiated. Nychia has lost the terminal antennal segment. The increasing unlikeness of the male claspers and the three segmented antennæ of Nychia approach the condition in the Anisopinæ. The Nychini usually have the flight wings reduced, accompanied by a small scutellum. When fully developed flight wings are present, the scutellum is large. This is true also of Paranisops, which belongs in the Anisopinæ, and is the most primitive of that subfamily.

I consider the Anisopinæ at the top of the series because: (1) They have oxyhæmoglobin and a pit on the anterior end of the commissure of the hemelytra; (2) the males possess stridulatory organs and a courting ritual (excepting Paranisops); (3) the antennæ are three-segmented; (4) in Buenoa and Anisops the female gonapophyses are uniform and long. The male genital capsule is closed behind and the claspers decidedly unlike on the two sides. The genitalia in these last two genera have reached such a stability and uniformity that they are of little value for purposes of specific determination.

The Anisopinæ are more at home in the open water, cruising about gracefully and in perfect equilibrium at some distance beneath the surface.

Besides the differences stated in the key the Notonectinæ and Anisopinæ are unlike in the character of the labrum.*

ANATOMICAL NOTES, TECHNIQUE AND TERMINOLOGY

A number of contributions have been made to our knowledge of the anatomy of the backswimming water bugs. Wefelscheid,[83] 1912, produced a study, "Uber die Biologíe und Anatomie von Plea," that is monographic in nature. Esaki [28] and China investigated the Helotrephidæ. In the Notonectidæ as now restricted Buenoa has been studied by Bare [4] and Anisops by Poisson.[68] Notonecta has been the object of many studies, for the most part in connection with some general problem dealing with mouthparts, wings, respiration,

* Except Paranisops which has labrum like Notonecta. Paranisops also has infracoxal plates hairy like Notonecta.

or genitalia. Some studies on embryology and cytology are also available. Several of these have considerable value to the systematist. Hutchinson,[41] in his "Revision of the Notonectidæ and Corixidæ of South Africa," figures the venation of the hind wings of Notonecta, Enithares, Nychia, Anisops and Plea. Specific differences in the ovipositors of American Notonecta (1918)[37] and in the genital capsules of the males (1919) were reported by Hungerford.[39] Since then the genitalia have been used in systematic papers by Hale, Jaczewski, Bare, Hutchinson, Despax, Poisson and Esaki.

Hutchinson, in the paper cited above, employed the cytological evidence in chromosome studies made by Browne,[16] in 1916 and by Poisson [69] in 1927 in his division of the genus Notonecta into the subgenera Notonecta S. Str. and Paranecta (new); the latter embracing *Notonecta lactitans* Kirk. and all the other species without digitiform extension of the male genital capsule and with short ovipositors in the female; the former, with *Notonecta glauca* L. as the type, and including species in which the males have the digitiform extension of the male capsules and elongate ovipositors. Hutchinson believes that the subgenus Paranecta is the older group because of the less specialized condition of the ovipostor, the simpler genital capsule and the larger number of chromosomes. Browne found that in *N. undulata* Say, *N. indica* Linn. (= *N. unifasciata* Guér. probably) and in *N. shooteri* Uhler, the diploid number of chromosomes is 26, the first spermatocyte division showing 14 (the sex chormosomes conjugate late) and the second 13.

In both *N. Glauca* Linn. of Europe and *N. irrorata* Uhler of North America the diploid number is 24, the first spermatocyte division showing 13 and the second 12. It would be very helpful if further cytological studies in the Notonectidæ were made.

The *Notonecta mexicana* A. & S. series, for instance, could be studied with profit. This group is in some respects quite distinct, and certain species such as *Notonecta lobata* Hungerford could be secured in large numbers in the southwestern United States. A study of *Notonecta handlirschi* Kirkaldy, which was placed in the new subgenus Enitharonecta by me in 1928,[40] should be made and compared with a study of some species of Enithares. Unfortunately we must first discover the breeding place of this unique Australian representative of the genus Notonecta. So far we know it only from the two specimens of the type series in the Vienna Museum which are labeled "Post., A. Fischer, 1878," and one other specimen.

In this paper it is necessary to present only such gross anatomical

features as may be useful in the separation of the species. The illustrations on Plates VI, IX and X will give an idea of the chief anatomical characteristics of the genus Notonecta.

In understanding the descriptions given in this paper it is important to note that the measurements have been made from above the dorsal side of the insect when held in a horizontal position. Care must be taken to have the longitudinal and transverse axes exactly horizontal. The length of the head, compared to median length of pronotum, has been determined by projection and not by tilting the insect out of position; so, also, in comparing length of vertex with its anterior width and the convexity of the anterior margin of the vertex with that of the frontal margin of the eye. The ratio of the anterior breadth of vertex to the synthlipsis is secured by measuring the distance between the eyes in front and the narrowest interocular space, the latter being called "synthlipsis."

The lateral margins of the prothorax are always more or less compressed dorsoventrally into a more or less thin edge, or ledge, which in some species is quite broad along the anterior portion. By viewing this edge from the side it is usually seen to be somewhat sigmoid, and, compared with the long axis of the insect, is either oblique or nearly parallel with it. The shape of this ledge may be quite different in the sexes of the same species.

The abdominal sternites are often of interest (see Plate X). In some species the edge of the mid-ventral keel is bare on one or more segments. The so-called "fourth abdominal sternite" is so designated for the convenience of the taxonomist. It is really the sternite of the fifth segment. In the females the shape of the last two abdominal sternites* afford excellent characters (see Plate X). In the *N. mexicana* A. & S. series the penultimate sternite is very narrow, in *N. montezuma* Kirk. it is long, broad and keel is bare; in *N. undulata* Say it is relatively long and cleft behind, while in *N. irrorata* Uhler it is broader than long. The last abdominal sternite is no less interesting. On Plate X I have figured four distinct types. Figure 1 illustrates the characteristic shape of the *N. mexicana* A. & S. series, figure 3 the usual shape of the subgenus *Paranecta* Hutchinson, and figure 4 that of the subgenus Notonecta. In Paranecta the first pair of gonapophyses are short and in Notonecta they are elongate.

* Also referring to those visible as the fifth and sixth. Of course they are actually the sternites of the sixth and seventh and the three pairs of gonapophyses are attached to the eighth and ninth. The genital capsule of the male belongs to the ninth segment.

The male genital capsules with their claspers or parameres afford good characters. There are three distinct groups of the genus based upon the shape of the capsule itself. The subgenus Enitharonecta, with its caudal projection and reduced lobes behind the claspers (see Plate VIII, fig. 4); the subgenus Paranecta, which lacks a digitate process (see Plate XIII); and the subgenus Notonecta, which possesses such a process (see Plates XVI and XVII). The male genital capsule is hidden within the last abdominal segment and must be drawn out into view, and for careful study must be cleared. Both operations are quite simple after a little practice. To remove the capsule moisten the insect with 5 per cent alcohol to relax it. After a few minutes hold the insect between thumb and finger of one hand and with the other, by means of a dissecting needle bent at the tip, reach in and bring out the capsule. It is often best to slip the needle in between the body wall and the capsule on both sides to loosen the connections before undertaking to draw out the capsule. To clear the capsule place it in caustic potash solution and either boil it for a time till clear or let it stand in the cold solution two or three days. I prefer the latter method. After washing the cleared capsule in water it can be studied under the binocular and then stored in a vial of alcohol (70 per cent) or dehydrated with alcohol, placed for a few minutes in xylol and mounted in a drop of balsam on a card or celluloid slip to be placed on the pin beneath the insect. Another method that is even better is to clear a little, wash in water, then place in a little dish of acetic acid. After ten minutes add a drop of clove oil, adding clove oil drop by drop every few minutes, and drawing off the excess with a pipette. After a time the capsule will be in pure clove oil, from which it can be mounted directly in a drop of balsam on a celluloid card for pinning beneath the insect. If the insect is then placed in a dust-free chamber until the mount hardens, this method will be found most satisfactory.

The ædeagus† also should be examined and the amount of clearing of the genital capsule must be enough to enable a study of the claspers and yet not enough to destroy the characters of the ædeagus, which in certain cases are useful. The difficulty in securing uniform clearing so that precise comparisons of scleratized parts can be made and the wide differences in the relative positions of the parts of the ædeagus in different individuals has led me to omit specific descriptions of this structure. The structure, called the "internal

† Phallic organ, according to Snodgrass.

stay" by Hutchinson[41] (see his Plate XXVIII, fig. 2), appears to be most developed in the *N. mexicana* A. & S. group and but slightly developed in the *N. lutea* Müller group.

THE BIOLOGY OF THE NOTONECTIDÆ

The backswimmers are among the best known of the water bugs. They inhabit the ponds and pools of nearly every land. The fact that they swim on their backs readily distinguishes them in their native element. They are predaceous creatures, the larger species often attacking insects and other animals, even small fish, larger than themselves. The small nymphs of Notonecta and probably all of the Anisopinæ, even in the adult stage, feed to a large extent upon the small Entomostracan life of the water.‡ The Anisopinæ have the two anterior pairs of legs margined with rather long spines, which form, when flexed, a splendid crib for the retention of ostracods, cladocera, etc., many of which may be held captive at one time.

Members of the genus Notonecta, and no doubt of the Enithares§ also, can inflict a severe "sting" with their beaks when incautiously handled, a fact which led to the use of the name "Wasser-bienen" by the early German writers. This disagreeable behavior has given them a place in the literature of Medical Entomology (see Riley and Johannsen Handbook of Medical Entomology). No doubt most of the observations in this regard have been made by collectors, but on several occasions I have been impressed by their reputation as "stingers" and their economic importance to the owners of commercial swimming pools. Instances have been reported to me in which the swimming pools have been so infested with these insects and the complaints so numerous among bathers that the elimination of the backswimmers became necessary to restore the popularity of the pools.

Most species winter as adults either hidden in the mud and other debris of the pool or remain more or less active as conditions may permit. They have been observed swimming beneath the ice in spring-fed pools in midwinter. There is some evidence, mostly unpublished, to indicate that certain species may also overwinter in the egg stage.* Some species have been observed to leave the shallow

‡ Anisops and Buenoa can be and have been reared in captivity upon mosquito wrigglers.

§ H. M. Hale in the Records of the South Australian Museum, Vol. II, No. 3, 1923, reports the "sting" of Enithares as similar to that of a bee sting.

* See under *N. lutea* Müller and *N. borealis* Bueno and Hussey.

temporary pools of summer to fly to deeper waters in which to winter.

There are some interesting records of countless swarms of Notonecta that for some reason have been precipitated from their flight in mid-air to drop like hail upon the ground. One such "rain of insects" recorded in the northern United States in 1846 covered an extent of at least twenty-five miles in one direction.

Sometimes Notonectidæ fly to trap lights, and Mr. R. A. Stirton, who collected these insects for me in Central America, drew them within reach of his net by the use of a flash light over the water.

Mating takes place in the water, and the courting maneuver of Buenoa, and probably most† other Anisopinæ,‡ includes stridulation of the males, which make a chirping sound by rubbing the front legs against the base of the beak as they approach the females. The eggs of some of the Notonecta (the majority) are affixed to aquatic vegetation and other supports in the water, while others insert their eggs more or less deeply into plant tissues. The oviposition of only one species of Enithares has been published, and this one affixed its eggs to aquatic vegetation. So far as known, all of them have the first pair of female gonapophyses short and weak and not adapted for piercing plant tissue. The Anisopinæ, on the other hand, with the exception of Paranisops, have well-developed gonapophyses and must insert their eggs as has been observed for some of the Buenoa. So far as known there are five nymphal instars, and there may be one or more generations, depending upon the species and the climate.

RELATIONS TO OTHER AQUATIC LIFE

The Notonecta are powerful swimmers, but not as fleet as the Corixids. Ordinarily they swim short distances, coming to rest back downward just beneath the surface film, the tip of the abdomen in contact with the surface, the body and head downward at such an angle that just the claws of the intermediate limbs may touch the surface and the hind limbs directed well forward of right angles to the body, poised for a sudden rowing stroke, or else they dive to cling to some submerged object. Certain species prefer open water, others the shelter of aquatic vegetation, and still others the dark, shadowy places beneath overhanging bushes. Some will

† Paranisops is doubtless mute.

‡ Hale in Records of the South Australian Museum, Vol. II, No. 3, 1923, p. 406, describes the courtship and stridulation of *Anisops hyperion* Kirk. which is very similar to observations made by Hungerford and by Bare of Buenoa.

live in muddy, stagnant little ponds, others only in cool, clear waters. For the most part the Notonecta live in standing bodies of water or in quiet pools of a watercourse. One species will tolerate the brackish waters by the sea, and some have been taken in the acrid coffee-colored waters of some peat-bog pool. As a group they are probably indifferent to a wide range of pH.

Their relation to the other small creatures of the water is that of predator. In their early stages they feed upon the small crustacea (Entomostraca mostly) and small insect larvæ; in their later stages upon larger forms, even small tadpoles and little fishes. In turn they may be taken and devoured by the naiads of dragon and damsel flies, by Belostomatids and Nepids and by predaceous water beetles. Now and then they are captured by some surface-dwelling insect or other animal. They are seldom eaten by the fishes, at least much less frequently than are the Corixids, which often dwell with them in large numbers.

Their contention for the same food* that small fishes eat and their destruction of the early stages of some of the fishes make them of some economic importance in fish culture. The economic relation of the Notonecta to the plant life of the water is trivial. Some species make incisions in the stems of plants for the deposition of their eggs, others merely attach them to the leaves and stems. While chlorophyl from Spirogyra has been found by Bare[3] in the stomachs of some Buenoa, it is not probable that the Notonecta feed directly upon plant life.

GEOGRAPHICAL DISTRIBUTION

The family Notonectidæ is represented by one or more species in nearly every land. Only one genus, however, has anything like a world-wide distribution. This is the genus Notonecta, and it has not been reported for the East Indian Archipelago, Philippine Islands, New Zealand, Tasmania, Madagascar, Hawaii or other Pacific insular groups. Furthermore there is but one species found in Australia, and this one is a curious species found only in west Australia (N. *handlirschi* Kirkaldy, known only from three specimens). It is the type of the subgenus ENITHARONECTA Hungerford and, as the name implies, is in some respects intermediate between Notonecta and Enithares. The other subgenera of the genus Notonecta are PARANECTA Hutchinson, BICHROMONECTA Hungerford, ERYTHRONECTA Hungerford and NOTONECTA Linnæus.

* G. C. Embody[26] records them killing amphlipods as large as themselves.

The subgenus PARANECTA appears to me to be the oldest. It is widely distributed in the Western Hemisphere, having 15 species in South America and 13 species covering Insular America, Central and North America. It is then the dominant subgenus of the Western Hemisphere. In the Eastern Hemisphere we find a species, *N. lactitans* Kirkaldy in Africa south of the Sahara, but not one in Europe! In eastern Asia we find 3 in China, 1 in eastern Siberia, 1 in Japan and 1 in Formosa. The distribution suggests that the subgenus may have arisen in the new world, and that the old-world species, namely the one in south Africa, those in eastern Asia, Japan and Formosa, represent the terminals of an early dispersal. Even the subgenus ENITHARONECTA in remote Australia may have developed from some ancestral PARANECTA.

In North America we have *N. insulata* Kirby and *N. kirbyi* Hungerford that represent a link between this subgenus and subgenus NOTONECTA. The former species occurs in northern United States and Canada east of 100th meridian and the latter in western Canada and western United States, ranging southward along the mountain chain. These two species, together with *N. impressa* Fieber (*N. montezuma* Kirkaldy) from Mexico and north into Texas form a distinct group of the subgenus PARANECTA.

Other groups in this subgenus can be distinguished, such as the *N. bifasciata* Guérin group, the *N. undulata* Say group, and the *N. chinensis* group.

Most of the South American species are small in size and much alike and belong to the *N. bifasciata* Guérin group. The *N. undulata* Say group consists of species of moderate size and is represented in South America by *N. fazi* Hungerford in Chile, its close relative *N. vereertbruggheni* Hungerford just over the mountains to the east, and *N. variabilis* Fieber in Brazil. *N. undulata* Say is widely distributed over North America from coast to coast. In the northern half of the United States and Canada it is readily recognized in the field, but as we proceed southward into the Lower Austral Zone we find it more and more replaced by *N. indica* Linnæus, which is an abundant species, not only in the southern states but in Cuba and Jamaica and extending southward from Mexico to Colombia. *N. variabilis* Fieber in Brazil is almost indistinguishable from *N. indica* Linnæus.

The *N. unifasciata* Guérin group, possessing angulate mesotrochanters and a black scutellum margined with flavous, ranges from Mexico northward into British Columbia. The species *N. uni-*

fasciata Guérin embraces several subspecies which in the northern ranges is often abundant in warm or so-called "hot springs." While no records of this species have been made from South America in recent years, there are two specimens in Kirkaldy's collection labeled "S. Amer." and called by him *N. americana*. There are also a few specimens in Vienna labeled "Frfld. Am." and "Frfld. 1874." Where they came from is uncertain.†

The subgenus BICHROMONECTA Hungerford may have arisen from the Paranecta, but has developed a striking reduction of the penultimate sternite in the female (see text figures, p. 101), a character anticipating the great reduction of this sternite in the next subgenus. The subgenus is typified by *N. shooteri* Uhler and occupies a restricted range from Colombia, South America, on the south to California on the north.

The subgenus ERYTHRONECTA Hungerford, of which *N. mexicana* Amyot and Serville is characteristic, occupies the same range as that of BICHROMONECTA Hungerford.

The subgenus NOTONECTA Linnæus: This subgenus represented by *N. glauca* Linnæus is characterized by having a digitate process on the male genital capsule. In most of the species the females have long ovipositors for inserting the eggs in the tissues of plants, a character not known in any of the other subgenera. It probably developed from the Paranecta through species much like *N. insulata* Kirby. The most primitive species are *N. maculata* Fabr. and *N. pallidula* Poisson etc., which have short ovipositors and merely attach their eggs to supports in the water, as do all the Paranecta known. Moreover the last abdominal sternite of the female is no more developed than in some species of Paranecta. This subgenus is dominant in Europe and North Africa, a territory, it will be remembered, in which Paranecta is absent. From southern Europe it spreads eastward to India, and from northern Europe we find a circumpolar group typified by *N. lutea* Müller in northern Europe, a species which follows the mountains southward to France, and by *N. borealis* Bueno and Hussey, a boreal species of North America.‡ The subgenus is represented also by a species in Burma, one in China, one in southwestern Siberia, and by *N. irrorata* Uhler in eastern North America. Thus there are 2 species in North America, 1 of them confined to the Boreal; 3 confined to Eastern Asia, 1 to

† It was supposed that these had been collected by Frauenfeld when Entomologist on the Novara which touched South America at Rio Janeiro, Brazil, and Valparaiso, Chile. This cannot be true, however, since the Novara made its trip around the world in 1857-1859.

‡ We must bear in mind also *N. nigra* Fieber described from Brazil, S. A. See discussion under this species.

Arabia, and 9 species and their subspecies which are found in Europe, the Islands adjacent thereto, and in North Africa. *N. maculata* Fabr. ranges east to India and *N. viridis kashmiriana* Hungerford represents the eastward distribution of this species.

Summarizing the distribution of the genus Notonecta Linnæus we find it well represented in the Western Hemisphere, in Europe, North Africa and Asia.§ It appears to be lacking entirely in the East Indian Archipelago, etc., where it is replaced by the genus Enithares. The genus is divided into five subgenera: PARANECTA, abundant in the Western Hemisphere, is represented in the Eastern Hemisphere by a few species in the Eastern Palæarctic and one in the Ethiopian. BICHROMONECTA and ERYTHRONECTA are confined to the region between Colombia, S. A., and California and New Mexico, U. S. A. The subgenus NOTONECTA is common in Western Palæarctic, has a few species in Eastern Palæarctic, only two species in Nearctic and possibly one in the Neotropical.* Finally the subgenus ENITHARONECTA, which is represented by a single species in the West Australian realm.

The above gives us a picture of the present distribution of the subgenera of Notonecta. Unfortunately there is little evidence in the fossil remains to help us locate the centers of dispersal, as will be seen in the following chapter. Most of our fossils are from the Tertiary and far too recent and too few to assist us. The one from the Jurassic suggests that the Notonectinæ and the Anisopinæ were already separated. The relation of the various genera and subgenera must be based, therefore, upon the morphology of present-day forms and what we may conjecture from their present distribution.

GEOLOGICAL DISTRIBUTION

Only a few fossil species of the family have been described, and these all appear to belong to the Anisopinæ.

The oldest fossil is described under the name *Notonecta elterleini* Deichmüller,[23] and comes from the lithographic chalk in Bayern (Jurassic). Kirkaldy[47] says it must belong to a new genus and Handlirsch[34] says it cannot belong to Notonecta S. Str.

All the other fossils are from the Tertiary and all but one from the old world. Six species from the upper Oligocene, one from lower Miocene, and one from the Florissant in Colorado (Miocene).

The curiously short and thickened front legs of *Notonecta jubata*

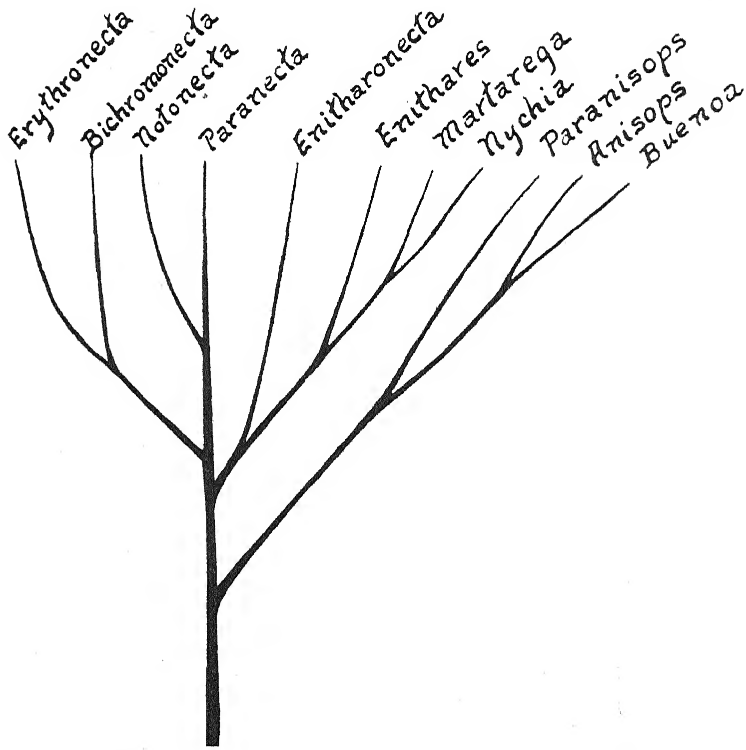
§ Records are lacking over vast stretches of this great continent, due probably to the few collections that have been made.

* *N. nigra* Fieber.

Schlechtendal and apparently also of *N. comata* Schlechtendal and *N. deichmüellari* Schlechtendal make them unlike anything living to-day. While Kirkaldy[47] places *N. hornacki* Schlechtendal as a true Anisops, there is no indication of a stridulatory protuberance on the tibia and the thickened femur suggests that the specimen is a male.

The other European species Kirkaldy either assigns a position near Buenoa or to undescribed genera. To my mind all of them belong in the second category.

Scudder's[76] *N. emersoni* from the Florissant is also impossible to place. If his interpretation that "the median forked line on its posterior portion seems to indicate the hemelytral suture of the upper surface seen through the body" is true, then the insect is a true Anisopinæ, because the claval orifice is present. I supposed from the drawing this was the midventral keel present in all Notonectidæ. The evidence is not clear that any of the fossils belong to existing genera, although the general shape is that of Anisopinæ.



TEXT FIGURE 1. Diagram illustrating the possible phylogeny of the genera and subgenera of the Notonectidæ.

TAXONOMY OF THE NOTONECTA

THE GENUS NOTONECTA LINNÆUS

(Logotype *N. glauca* Linnæus)

1758. Notonecta Linnæus; Systema Naturæ, 10th Edn., p. 439. (For other references see Van Duzee's Catalogue of the Hemiptera, pp. 449-450.)

1801. Notonecta Linnæus; Lamarck, Syst. Nat. Anim. s. Vert., p. 296, names *N. glauca* Linn. as type.

Besides the diagnosis given in the key, the following characteristics may be noted: *

The head shorter than the pronotum. Lateral margin of pronotum compressed dorsoventrally into an edge. Hemelytra clothed more or less with short, flattened hairs. Sides of thorax densely clothed with rather long, flattened hairs. The infracoxal plates covering the bases of the hind coxæ not longitudinally carinate but densely clothed with long hairs.

Male genital capsule with or without a ventral digitiform process. Claspers † or parameres symmetrical.

KEY TO SUBGENERA OF NOTONECTA

A. Last two abdominal sternites of male normal (not long and slender). Male genital capsule not produced caudally on its ventral line, caudal lobes behind claspers not greatly reduced. Claspers not large thin plates.

B. Genital capsule of male without digitiform process. The last abdominal sternite of female not enlarged.

C. Keel of fourth abdominal sternite usually not bare. Eyes normal in size, or if broad not as broad as length of the lateral margin of the pronotum. Penultimate abdominal sternite of female not slender. (See Plate X.)

D. Anterior trochanter of male with or without small hook and with no basal protuberance. Penultimate abdominal sternite of female more or less rectangular.......................... *Paranecta* (Hutchinson).

DD. Anterior trochanter of male with large, stout hook and a basal protuberance. Penultimate abdominal sternite of female triangular, its tip overlapping base of last segment. (See text figure 7.) *Bichromonecta* (Hungerford).

CC. Keel of fourth abdominal sternite always bare. Eyes unusually broad, about as broad or broader than the short lateral margin of the pronotum. Penultimate abdominal sternite of female slender. .*Erythronecta* (Hungerford).

BB. Genital capsule of male with a digitiform process. The last abdominal sternite of female enlarged and usually constricted just before the tip. *Notonecta* (Linnæus).

AA. Last two abdominal sternites of male long and slender. Male genital capsule produced caudally on its ventral line, caudal lobes behind claspers reduced. Claspers large thin plates. Known only from Australia............. *Enitharonecta* (Hungerford).

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* Mr. Hutchinson [41] adds statements regarding the venation of the hind wings; they are not correct for the genus. Using his nomenclature *Notonecta lobata* Hungerford has M-Cu strongly "chitinized" and many species show Cu_1 and Cu_2 not only "chitinized" at base, but complete throughout and united distally as in his figure of the wing of *Enithares sobrina* Stal. (Plate XXVII, fig. 5.)

† Snodgrass proposes the name harpagones for these.

Subgenus PARANECTA Hutchinson 1929

(Type species *Notonecta lactitans* Kirkaldy)

Hutchinson, G. E., Annals South African Museum, Vol. XXV, Pt. 3, p. 363.

Notonecta in which the male genital capsule lacks a digitiform process and in which the females have the first pair of gonapophyses short and weak. The females have the penultimate abdominal sternite rectagular. The last abdominal sternite of female is not large and is usually incised at tip (see Plate X, fig. 3). The diploid number of chromosomes for those known is 26.

Subgenus BICHROMONECTA Hungerford 1934

(Type species *Notonecta shooteri* Uhler)

Hungerford, H. B., Jl. Kans. Ento. Soc., Vol. VII, No. 3, p. 98.

Notonecta of compact form with two color phases, one luteous and the other pigmented. The luteous form has reduced flight wing, reduced posterior lobe of membrane, smaller scutellum and less prominent humeri, resulting in more nearly parallel lateral margins of pronotum. The pigmented form has normal wings and more prominent humeri. Eyes are flattened and anterior margins oblique; synthlipsis relatively broad. Anterolateral angles of pronotum embracing the eyes and lateral margins straight to convex. The females have the penultimate abdominal sternite triangular, its tip notched and overlapping the base of the last segment (see text figures, p. 101). The males have a protuberance at the angle and a broad stout hook on the anterior trochanter (see Plate IX, fig. 4). The "internal stay" of the ædeagus is recurved at tip.

Subgenus ERYTHRONECTA Hungerford 1934

(Type species *Notonecta lobata* Hungerford)

Hungerford, H. B., Jl. Kans. Ento. Soc., Vol. VII, No. 3, p. 98.

Notonecta of compact form, usually red and black in color. The genital capsule of the male lacks a digitiform process and the "internal stay" of ædeagus is heavily sclerotized. The first pair of gonapophyses of the female is short. The so-called fourth abdominal sternite is broad and short in both sexes and the keel is bare. The penultimate abdominal sternite of the female is very slender and the last one is narrow and usually emarginate at tip (see Plate X, fig. 1).

Subgenus NOTONECTA Hutchinson 1929

(Type species *Notonecta glauca* Linn.)

Hutchinson, G. E., Annals South African Museum, Vol. XXV, p. 363.

Notonecta in which the male genital capsule is provided with a digitiform process and in which the females have the first pair of gonapophyses well developed. The last abdominal sternite of female is large and usually constricted just before the tip, which is not incised. The diploid number of chromosomes for those known is 24 (see Plate X, fig. 4.)

Subgenus ENITHARONECTA Hungerford 1928

(Type species *Notonecta handlirschi* Kirkaldy.)

Hungerford, H. B., Annals Ento. Soc. America XXI, p. 143.

Resembles other Notonecta in general appearance, but decidedly unlike them in shape of last two abdominal sternites of male, which are long and slender, and in the shape of the genital capsule of the male, which is produced caudually on its ventral line. The claspers or parameres are large, thin plates convex without and concave within. The caudal lobes of the capsule are greatly reduced. (See Plate VIII, fig. 4.)

NOTONECTA OF EASTERN HEMISPHERE

KEY TO NOTONECTA OF EASTERN HEMISPHERE

1. Small species, not to exceed 12 mm. long or 4 mm. across humeri*............... (2)
   Species larger than above.. (3)
2. Species plump. Middle femur with distinct spiniferous tubercle near base of rear margin. Last two abdominal sternites of male slender..........*N. handlirschi*. (Australia, p. 27.)
   Species slender, at least three times as long as broad. Middle femur without the distinct tubercle mentioned above. Last two abdominal sternites of male normal ....*N. lactitans*. (S. Africa, p. 28.)
3. Male genitale capsule without digitate prolongation; last abdominal sternite of female not large and constricted near the tip. (See Plate X, fig. 3)............. (4)
   Male genital capsule with digitate prolongation; females of most species with last abdominal sternite large and constricted near the tip. (See Plate X, fig. 4).... (9)
4. Mesotrochanter right angulate....................................*N. kirkaldyi*. (China, p. 30.)
   Mesotrochanter with angle produced.. (5)
5. Typical color, red and black... (6)
   Typical color flavous and black.. (7)
6. Hair on ventral side of body silvery gray to light brown. Lateral margin of pronotum not sharp-edged. Anterior margin of vertex, seen from above, not flattened ....*N. chinensis*. (China, p. 31.)
   Hair on ventral side of body black. Lateral margin of pronotum sharp-edged. Anterior margin of vertex, seen from above, flattened..............*N. saramoa*. (Formosa, p. 32.)

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* Poisson described his *N. pallidula* as 11.5 mm. to 12 mm. long; all specimens I have seen are at least broader than 4 mm. and most of them longer than 12 mm.

7. Mesotrochanter produced, but not into a long, sharp, thornlike process.......... (8)
Mesotrochanter produced into long, sharp, thornlike process. (See Plate IX.)
N. kiangsis.
(China, p. 33.)
8. Connexivum black beneath.................................*N. immediata.*
(E. Siberia, p. 35.)
Connexivum green to flavous..............................*N. triguttata.*
(Japan, p. 36.)
9. Mesotrochanter right angulate. General facies reddish-orange, unevenly marked with black ....*N. montandoni.*
(China, p. 37.)
Mesotrochanter rounded .... (10)
10. Last abdominal sternite of female not constricted near the tip. (See Plate X, fig. 3), (11)
Last abdominal sternite of female constricted near the tip (see Plate X, fig. 4) or large and depressed on sides before the tip............................ (14)
11. Scutellum pale, sordid brown...............................*N. pallidula.*
(N. Africa, p. 38.)
Scutellum black .... (12)
12. Anteapical tooth of mesofemur of normal size. (See Plate VI, fig. 5.) Metanotum and first abdominal tergite orange or yellow........................... (13)
Anteapical tooth of mesofemur unusually long. Metanotum black....*N. canariensis.*
(Canary Islands, p. 40.)
13. Anterolateral angles of pronotum slightly produced.................*N. maculata.*
(Western and Southern Europe, North Africa, and eastward to India, p. 41.)
Anterolateral angles of pronotum obtuse......................*N. meinertzhageni.*
(Hoggar Mountains in the Sahara, p. 44.)
14. Last abdominal sternite of female large and slightly depressed on the sides before the tip ....*N. arabiensis.*
(Arabia, p. 44.)
Last abdominal sternite of female strongly depressed on the sides before the tip or strongly constricted before the tip...................................... (15)
15. Anterior angles of pronotum not acute or closely embracing the eyes. (See Plate VIII, fig. 8).. (16)
Anterior angles of pronotum acute and closely embracing the eyes. (See Plate XVII, fig. 4).. (26)
16. Scutellum typically entirely black.. (17)
Scutellum not entirely black.. (25)
17. Large reddish species, more than 6 mm. across humeri................*N. violacea.*
(Burma, p. 45.)
Species not surpassing 5.4 mm. across humeri.................................. (18)
18. Hemelytra typically yellowish or flavous, lacking oblique stripes.................. (19)
Hemelytra reddish or brownish, maculated or not.............................. (20)
19. Hemelytra typically yellowish or flavous, with brownish or blackish maculations (sometimes confluent) along costal margin, and often a transverse spot at apex of clavus and internal angle of corium.....................*N. glauca glauca.*
(Northern Europe and southward to Central France, p. 46.)
Hemelytra yellowish or flavous with a broad transverse black band covering distal third of corium, tip of clavus and basal portion of membrane..*N. glauca poissoni.*
(Asia Minor, p. 49.)
20. Hemelytra reddish or brownish, maculated or not............................ (21)
Hemelytra largely velvety black with one or two flavous stripes at the base....... (22)
21. Hemelytra more or less strongly maculated, presenting at the base either one pale longitudinal stripe on the clavus, or two such stripes, one on the clavus and the other on the corium...................................*N. glauca hybrida.*
(Southern France to North Africa, p. 50.)
Hemelytra generally clear reddish, sometimes with some vague markings of dull black in the marginal canal and some drop-shaped spots on the disc.
*N. glauca rufescens.** (*N. glauca fulva?*)
(Southern Europe, N. Africa, p. 51.)

* Doctor Poisson mentions a new subspecies. *N. glauca kirvillei*, from Asia Minor, which he says is related to this.

22. Size usually 15 to 16 mm. .... (23)
Size usually 13 to 14 mm. (If larger with only one pale stripe on hemelytron)..... (24)
23. Hemelytra with two very clear flavous stripes at the base, the one on corium a little shorter than the one on the clavus........................*N. obliqua obliqua.*
(Northern Europe to Central France, p. 51.)
Hemelytra as above, plus one large flavous spot beyond distal end of the stripe on corium ....*N. obliqua delcourti.**
(Belgium and Northwestern France, p. 54.)
24. Hemelytra with two flavous stripes, but the one on corium more or less restricted or only the claval stripe present, and perhaps some yellowish spots in place of the corial stripe ....*N. obliqua meridionalis.*
(About the Mediterranean, p. 54.)
25. Size very large: 17 mm. to 18.3 mm. long. Last abdominal sternite of female greatly and abruptly constricted before the tip....................*N. amplifica.*
(E. Siberia, p. 55.)
Size seldom over 15 mm. long. Last abdominal sternite of female only moderately and not abruptly constricted before the tip..........................*N. lutea.*
(N. Europe, p. 56.)
26. Scutellum seldom entirely black, sometimes entirely pale. Anterior trochanter of male with a hook... (27)
Scutellum solid black. Anterior trochanter of male with slight elevation.......... (28)
27. Synthlipsis usually not over half the width of the eye. Last abdominal sternite of female only moderately and not abruptly constricted before the tip. Male clasper as on Plate XVII, fig. 2..................................*N. lutea.*
(N. Europe, p. 56.)
Synthlipsis over half the width of the eye. Last abdominal sternite of female abruptly constricted before the tip. Male clasper as on Plate XVII, fig. 1..*N. reuteri.*
(N. Europe, p. 59.)
28. Hemelytra flavous or greenish flavous, costal margin often maculated and a dark X-shaped figure at tip of hemelytral commissure.............*N. viridis viridis.*
(Western Europe from France southward, north Africa, p. 60.)
Hemelytra largely maculated.. (29)
29. Anterior margin of head as seen from above slightly convex. Genital claspers of male like above....................................*N. viridis mediterranea.*
(Mediterranean region and eastward, p. 63.)
Anterior margin of head as seen from above flattened. Genital claspers of male as shown on Plate XVII, fig. 5..........................*N. viridis kashmiriana.*
(Kashmir, p. 65.)

Notonecta handlirschi Kirkaldy 1897

(Color Plate IV, fig. 2, Plates VIII, fig. 4, and IX, fig. 7.)

1897. *N. handlirschi* Kirkaldy, Trans. Ento. Soc. London, p. 408.
1904. *N. handlirschi* Kirkaldy, Wien. Ento. Zeit. xxiii, p. 132.
1923. *N. handlirschi* Kirkaldy; Hale, Rec. S. Aust. Mus., Vol. II, No. 3, June 30, p. 418.
1928. *N. handlirschi* Kirkaldy; Hungerford, Annals Ento. Soc. Amer. xxi, p. 143, Pl. ix, fig. 6. (Fig. genital capsule.) (New subgenus Enitharonecta.)
1929. *N. handlirschi* Kirkaldy; Hutchinson, Annals of the South African Museum, Vol. xxv, Part 3, p. 363.

Size. Length 10 mm. to 10.5 mm.; width of pronotum 3.5 mm. to 4 mm.

Color. As shown on Color Plate IV, fig. 2. A species with reddish hemelytra sometimes nearly black, with clavus dark reddish brown. Metanotum and dorsum of abdomen rufotestaceous. Venter black.

Structural Characteristics. Anterior outline of head viewed from

* A variety, not a subspecies.

above flattened; vertex slightly shorter than its anterior width; margin of vertex less convex than the margin of the eye; anterior breadth of vertex:synthlipsis::22:13.* Pronotum twice the length of the head; lateral margins straight and moderately divergent; anterolateral angles produced forward beyond the caudolateral margins of the eyes; lateral ledge as seen from the side slightly curved, oblique and about as long as rear margin of the eye below it. Scutellum longer than the pronotum. Hemelytral commissure shorter than pronotum; posterior lobe of membrane well developed. Anterior trochanter of the male without hook or elevation. Mesotrochanter rounded or faintly angulate; mesofemur with distinct spiniferous tubercle on base of caudal margin; the distal mesofemoral tooth not prominent. The last two abdominal sternites long and slender in the male; the lobe of ninth tergite slender and pointed. The male genital capsule as shown on Plate VIII, fig. 4. The claspers are thin plates, convex without and concave within; as one views the clasper from the rear there is a recurved, short submarginal fold parallel with the upper margin; a much lesser thickening occurs before the tip below the upper margin; neither of these is visible from the lateral view.

Location of Type. Two males in the Vienna Museum. They bear the label "Fischer, Austr. Post 1, 1878." One of them now (1928) has the abdomen damaged by dermestids.

Comparative Notes. This species, the only one in the genus reported for Australia, appears to stand quite alone. For this reason I have placed it in a subgenus by itself.

Data on Distribution. There is a male specimen in the British Museum labeled "Western Australia, 1922-1923, B. R. Lucas." In this specimen the scutellum is black and the hemelytra nearly black, with the clavus dark reddish brown.

Notonecta lactitans Kirkaldy 1897

(Color Plates IV, fig. 3 and V, fig. 12; Plates VIII, fig. 9 and IX, fig. 8.)

1897. *N. lactitans* Kirkaldy, Ann. Mag. Nat. Hist., (6) xx, p. 58.
1897. *N. lactitans* Kirkaldy, Trans. Ento. Soc. London, p. 405.
1904. *N. lactitans* Kirkaldy, Wien. Ento. Zeit., xxiii, p. 132.
1925. *N. lactitans* Kirkaldy; Hungerford, Annals Ento. Soc. Am., xviii, p. 117.
1929. *N. lactitans* Kirk.; Hutchinson, Annals of South African Museum, xxv, Pt. 3, pp. 363 and 365-368. (Type of Paranecta subg. n.) Pl. xxvii, figs. 1, 2 and 3 (Head and pronotum, mesofemur and hind wing); Pl. xxviii, figs. 1, 2 and 3 (Genital capsule, aedeagus and clasper); Pl. xxix, figs. 10 and 11 (Head and pronotum of ? 3rd and 5th instars).

* Kirkaldy says: "Vertex not quite as wide as synthlipsis." This is not true in the types which I have examined on two occasions.

Referring to this species, also:

1897. *N. lactitans* var. *stygica* Kirkaldy, Trans. Ento. Soc. London, p. 406. This is the male of *N. lactitans* Kirk.

1904. *N. lactitans* var. *stygica* Kirkaldy, Wien. Ento. Zeit., xxiii, p. 132. (Name listed only.)

Size. Length 10.5 mm. to 12 mm. The females longer than the males. A slender species that is at least three times as long as broad.

Color. A yellowish gray and black species as shown on Color Plates IV and V. The males are darker than the females. Scutellum is black. Scutellum and hemelytra covered sparcely with short, fine, golden pubescence. Abdominal dorsum and venter dark.

Structural Characteristics. Head small, notocephalon very faintly longitudinally carinate on posterior half. Vertex broad at base. Anterior breadth of vertex : synthlipsis :: 5.6:3.5. Pronotum twice as long as the head, anterior angles obtuse, lateral margins slightly divergent and sinuate; lateral marginal ledge nearly straight terminating caudally below the humeral elevation. Scutellum slightly longer than the pronotum. Outer lobe of membrane very slightly longer than inner. Anterior trochanters of male without hook. Mesotrochanters slender, rounded, a small tuft of long hairs at the base. Mesofemur with tuft of bristle-like hairs on basal angle of rear margin. The subapical tooth directed slightly toward apex. Small tuft of hairs on median line of the short third ventral abdominal segment, fourth ventral abdominal segment longest, terminal one in female deeply notched. Male genital capsule as shown in Plate VIII, fig. 9. First pair of gonapophyses of female short.

Location of Types. Kirkaldy recorded the type as being in his own collection and listed: "Africa, Guinea (my coll.); Gaboon (Vienna Mus.); Cape of Good Hope (Paris Mus.)". The type, a female, broken and dismembered is in the U. S. N. M. with the Kirkaldy collection. In the Vienna Museum there is a female labeled cotype and "Gaboon Coll. Signoret." Thorax on the left side has been eaten by dermestids (1928). In the Paris Museum there is also a female bearing a red label "Comp. with type by Kirkaldy in Kirkaldy Coll." This is the specimen mentioned by Kirkaldy as from Cape of Good Hope. It carries the label "Museum Paris. Cap de Bonne Esperance. Delalande 1820." The type of *N. lactitans* var. *stygica* Kirk. is in the British Museum. It is only the dark male of *N. lactitans* Kirkaldy.

Comparative Notes. The most slender Notonecta known and the only representative of the Genus in Africa south of the Sahara.

The males are usually darker than the females, the hemelytra being blackish with the outer margin of the embolium, a streak on outer edge of clavus and a spot on the inner part of the posterior margin of the corium dull yellow. As Mr. Hutchinson has pointed out, this species is quite distinct, but more nearly related to the Western Hemisphere forms than to the European. It is the type of Hutchinson's subgenus Paranecta.

Data on Distribution. Besides the type localities listed by Kirkaldy, Mr. Hutchinson has recorded some thirteen collections in the Cape and believes that: "In the Cape Peninsula there is a migration from mountain pools in the autumn to low-lying waters on the Cape Flats and elsewhere in which the insects breed, the newly emerged adults then ascending and populating the localities left by their parents." I have specimens kindly sent to me by F. W. Pettey from Elsenbourg, S. Africa, and from Muilder's Vlei, Cap. Prov. There are four specimens in Dr. Herbert Osborn's collection "Vlei Su Pr. Common June 6, 1909."

Character of Habitat. The specimens sent to me by Mr. Pettey are from a clear mountain stream pool. Hutchinson records collections from reservoir, bog, pond, weedy pool and pools in streams. The elevations range from low flats to a pool near the top of a pass in the mountains. The highest elevation he gives is 4,200 feet.

Life History Notes. Hutchinson says the eggs are unknown, but presumably are laid on submerged objects without being imbedded. He describes what he believes to be the third, fourth and fifth instars.

Notonecta kirkaldyi Martin 1902

(Color Plate V, fig. 9; Plate XV, fig. 3.)

1902. *N. kirkaldyi* Martin; Bull. Mus. d'Hist. Nat. (Paris), viii, p. 336.
1904. *N. kirkaldyi* Martin; Kirkaldy, Wien. Ento. Zeit., xxiii, pp. 95 and 132.
1925. *N. kirkaldyi* Martin; Esaki, Notula Entomologicæ, v. p. 14.
1925. *N. kirkaldyi* Martin; Hungerford, Annals. Ento. Soc. Am., xviii, p. 418.

Size. Length, 13 mm.; width across thorax, 4.6 mm.

Color. A reddish orange and black species. Head and limbs of usual testaceous color. Scutellum black. Hemelytra reddish orange and black; the distal end of clavus, a stripe on corium bordering clavus and a broad irregular band of black crossing distal half of corium; the membrane is dark brown to black.

Structural characteristics. Anterior breadth of vertex : synthlipsis :: 7:3; head appearing fairly long; its length to that of pronotum :: 2.5:4.2. Lateral margins of pronotum diverging and nearly

straight; anterior angles normal; lateral ledge, seen from the side, straight with rear end turned upward beneath the humeral elevation. The scutellum a little longer than pronotum (nearly 5 to 4). Posterior lobe of membrane slightly longer than anterior. Anterior trochanter of the male without hook or tooth. Mesotrochanter right angulate. Mesotibia with slight prominence on rear margin. Female not examined by me. Male genital capsule as shown on Plate XV, fig. 3.

Location of Type. Paris Museum, cotypes in U. S. N. M. and in my collection.

Comparative Notes. A smaller species than *N. chinensis* Fallou and with the trochanter of middle leg right angulate instead of acutely angulate.

Data on Distribution. Described from "Yun-Nan-Nansen (Mgr. Excoffier) R. Oberthur. 1898." There were 31 specimens in the type series in the Paris Museum, all labeled as above.

Notonecta chinensis Fallou 1887

(Color Plate V, fig. 8; Plate XV, fig. 8.)

1887. *N. chinensis* Fallou; Le Naturaliste (Deyrolle Paris), viii, p. 413.

1894. *N. chinensis* Fallou; Bergroth, Rev. Ento. franc., xiii, p. 164. Redescribed at length.)

1897. *N. chinensis* Fallou; Kirkaldy, Trans. Ento. Soc. London, 1897, pp. 415, 416.

1904. *N. chinensis* Fallou; Kirkaldy, Wien. Ento. Zeit., xxiii, pp. 95 and 132.

1912. *N. chinensis* Fallou; Oshanin, Katalog der paläarktischen Hemipteren, p. 91.

1925. *N. chinensis* Fallou; Esaki, Entomolog. Mitteilungen, xiv, 1925, Nr. 5/6, p. 312.

1925. *N. chinensis* Fallou; Hungerford, Annals Ento. Soc. Am., xviii, p. 418.

1930. *N. chinensis* Fallou; Hungerford, Bull. Brook. Ento. Soc., xxv., No. 3, p. 138.

1930. *N. chinensis* Fallou; Kiritshenko, Annuaire du Musée Zoölogique de l'Académie des Sciences de l'U. R. S. S., p. 434.

Referring to this species, also:

1873. *N. sinica* Walker, Cat. Hem.-Het. Brit. Mus., viii, p. 204. (Kirkaldy.)

Size. Length, 13-14 mm.; width across thorax, 4.5 mm. to 5.1 mm., the females averaging a little larger than the males.

Color. An orange-red and black species. Head, pronotum and limbs light testaceous. Face, limbs and connexivum beneath may be greenish. Scutellum black. Hemelytra orange-red to red-brown with an undulating bluish-black band (occasionally represented by scattered spots) extending from suture to lateral margin, near the apical margin of the corium, but diverging from that as it approaches the lateral margin; membrane bluish-black.

Structural Characteristics. Eyes close together at synthlipsis; anterior breadth of vertex : synthlipsis : : 26 : 7; head about five-

eights as long as pronotum. Lateral margins of pronotum divergent and sinuate; anterior angles somewhat produced; lateral ledge as seen from the side slightly sigmoid. Scutellum a little longer than pronotum. Lobes of membrane about equal in length. Anterior trochanter of male with a median raised dentation in place of hook; mesotrochanter acutely angulate, the angle produced. Terminal abdominal sternite of female with lateral margins concave and apex shallowly notched. Female gonapophyses of moderate length. Male genital capsule as shown on Plate XV, fig. 8.

Location of Type. Fallou collection in Paris Museum. The male type is from Fo-Kien.

Comparative Notes. This species is readily separated from other oriental Notonecta (except *N. kiangsis* Kirk. and *N. saramoa* Esaki) by the very narrow interocular space (synthlipsis). *N. kiangsis* Kirk is very different in color, more slender in form, and the angle of the mesotrochanter is produced into a long, sharp thorn-like process.

Data on Distribution. Kirkaldy says, "Well distributed over the Chinese Empire" and gives the following: "Pekin, Kian-Si, Se-Tchouen, Chen-Si (Paris Mus.) Kin Kiang (? Chin-Kiang), Foo-Chan (Brit. Mus.) Fo.-Kien (Fallou and Bergroth Co.), Ngan Hoei, (Montandon and my colls.)."

The following additions I have noted: "Prov. Fo Kien (China) G. Siemssen vend. 31-v-1904 (Hamburg Mus.)"; "Chin Kiang, China V, 20, 1924, E. Suenson" (my coll.); Peking, China, Oct., 1925, P. W. Claassen, (my coll. and Cornell); Hweisin, Kansu, China (my coll.).

Notonecta saramoa Esaki 1933

(Plate XV, figure 7)

1933. *N. saramoa* Esaki; Trans. Nat. Hist. Soc. Formosa, Vol. XXII, pp. 493-495.

Size. Length, 13.5 mm. to 14 mm.; width across thorax, 4.5 mm. to 5 mm.

Color. An orange-red and black species resembling very closely *N. chinensis* Fallou. The broad, black band commonly present across the end of the clavus and corium in *N. chinensis* Fallou is replaced by three angular spots in the four paratypes before me. However, the species from China sometimes has identically these markings. Hair on ventral side of body black.

Structural Characteristics. Eyes close together at synthlipsis; anterior margin of vertex, seen from above flattened; anterior breadth of vertex : synthlipsis :: 29:9. Head about half as long as pronotum;

lateral margins of pronotum divergent, slightly sinuate in the male, more so in the female; anterior angles somewhat produced; lateral ledge as seen from the side thin and sigmoid. Scutellum a little longer than pronotum. Lobes of membrane about equal in length. Anterior trochanter of male with a median raised dentation in place of a hook; mesotrochanter acutely angulate, the angle produced. Terminal abdominal sternite of female with lateral margins concave and apex faintly incised. Male genital capsule as shown on Plate XV, fig. 7.

Location of Type. In collection of Professor Teiso Esaki. Four paratypes in the Francis Huntington Snow Entomological Museum. These paratypes are labeled: "Formosa," "Meoto-ike (Taichu-shu) near Kunugigaoka, 8,000 ft., 17 - VII, 1932, Teiso Esaki." and were collected in a small pond with the holotype in central Formosa. Other paratypes were collected in Mururoafu-no-ike, a larger pond 7,500 ft. in Taiheizan district, Northern Formosa, on July 23, 1932, by Professor Esaki. Paratypes will also be found in the collections of the Government Research Institute of Formosa, Taihoku and in the British Museum.

Comparative Notes. This species is near *N. chinensis* Fallou, from which it is distinguished by its more truncate head, by the thin lateral edge of pronotum, by the black hair on the ventral side of the body, by shape of genital capsule and mesotrochanter.

Data on Distribution. Known only by the type series from Formosa.

Notonecta kiangsis Kirkaldy 1897

(Color Plate V, fig. 7; Plate XV, fig. 5.)

1897. *N. chinensis* Fallou var. *kiangsis* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 416.
1904. *N. chinensis* Fallou var *kiangsis* Kirkaldy, Wien. Ento. Zeit., xxiii, p. 132 (lists name only).
1925. *N. kiangsis* Kirkaldy; Esaki, Notul. Entom., Helsingfors v, p. 15.
1929. *N. kiangsis* Kirkaldy; Hutchinson, Annals S. African Museum, xxv, pt. 3, p. 363.
1930. *N. kiangsis* Kirkaldy; Hungerford, Bull. Brooklyn Ento. Soc., xxv, p. 138.
1930. *N. kiangsis* Kirkaldy; Kiritchenko, Annuaire du Músee Zoöl. de l'Académie des Sciences de l'URSS., pp. 436 and 440.

Referring to this species, also:

1925. *N. bergrothi* Esaki, Notul. Entom. Helsingfors v, p. 14.
1925. *N. bergrothi* Esaki, Entom. Mitt., Berlin-Dahlem, xiv, p. 313 (fig. 1).
1925. *N. suensoni* Hungerford, Annals Ento. Soc. America, xviii, p. 417.
1926. *N. suensoni* Hungerford, Annals Ento. Soc. America, xix, p. 92. (Syn. note = *N. bergrothi* Esaki).

Size. Length of male, 12.5 mm.; of female, 13.8 mm.; width across the eyes, male, 2.28 mm.; female, 3 mm.; width across widest part of pronotum, male, 4 mm., female, 4.5 mm.

Color. General color luteous. Scutellum black. Sparse silvery pubescence on hemelytra. Brownish-black band along apical margin of clavus (caudal half of elytral commissure); slender, brown line on base of clavocorial suture, and another longitudinal line on disk of corium; margins and distal third of embolium more or less brownish; distal portion of corium marked with two nearly quadrate brownish-black areas, one before the other, the posterior one larger and both covered with conspicuous silvery hairs; inner angle of corium and inner base of membrane embrowned. Venter black. The ventral side of the connexivum greenish.

Structural Characteristics. Head long; eyes close together at synthlipsis; vertex : synthlipsis :: 5:1. Lateral margins of pronotum divergent, sinuate, and narrowly explanate; anterior angles acute; lateral ledge, as seen from the side, faintly sigmoid and ending caudally just beneath the humeral elevations, which are not marked. Scutellum slightly longer than pronotum. Anterior lobe of hemelytral membrane slightly longer than posterior lobe. Anterior trochanter of male with a small tubercle, two-fifths of distance from base to apex. The angle of the mesotrochanter produced into a long, slender, pointed process. Small hair tuft on median line of third ventral abdominal segment, fourth ventral abdominal segment longest. Last ventral segment of female but shallowly notched. First pair of gonapophyses of female short. Male genital capsule as shown on Plate XV, fig. 5.

Location of Types. In Paris Museum. At the end of his discussion of *N. chinensis* Fallou, Kirkaldy says: "To this species I have referred four specimens in the Paris Museum (from Chen-Si, Se-Tchouen, and Kiang-Si) which seem sufficiently distinct to bear a varietal name—*kiangsis* var. nov." This was followed by a short description of color. Since Kirkaldy gave it as a variety name, and gave only a color description, it was assumed by both Professor Esaki and me that his variety was structurally identical with *N. chinensis* Fallou. We, therefore, independently, but the same year, 1925, described as new, specimens that came to our hands. Sometime later Esaki found three specimens in the Paris Museum labeled by Kirkaldy "*Notonecta chinensis* Fallou var. 1897" that bear the locality labels mentioned above. While not bearing the name *kiangsis* nor marked types, they certainly are to be so considered. In 1928 I also examined these specimens. How anyone of Dr. Kirkaldy's experience could have thought them to be a variety of *N. chinensis* Fallou is a puzzle to me.

Comparative Notes. This species is very distinct from any others of the orient. It differs from all of them by its pale color and more slender shape. It differs from *N. montandoni* Kirkaldy, *N. violacea* Kirkaldy, *N. Kirkaldyi* Martin and the *N. glauca* group in having the angle of the mesotrochanter plainly produced. In this respect it is like *N. triguttata* Motsch. and *N. chinensis* Fallou, from which it is readily separated by this process being longer and sharper. The claspers of the male are also different.

Data on Distribution. Esaki described his specimens from Amur and Ussuri and says in his 1927 paper: "This species is now known to be widely distributed in Central and Northeastern China and East Siberia." There are also many specimens from South Ussuri in the Zoölogical Museum of the Academy of Sciences, St. Petersburg (Leningrad) and a single specimen from "China meridionalis in the Hungarian National Museum, Budapest." My specimens are as follows: "Shanghai, China, April 22, 1923; E. Suenson. (Holotype and allotype of *N. suensoni* Hungerford"; "Tsing Hua Col. Peking, China, 11-8-1924, P. W. Claassen"; another collection in 1925 at same place by Doctor Claassen; Mr. Suenson also sent me some collected April 18, 1926, from Shanghai; Hweisin, Kansu, China (my coll.); Dr. Kiritshenko gives southeastern Siberia, Manchuria, Korea, North China and the oriental region.

Character of Habitat. I have no data on this point.

Notonecta immediata Kiritshenko 1930

(Color plate V, fig. 6.)

1930. *N. immediata* Kiritshenko, Anniaire du Musée Zoölogique de l'Académie des Sciences de l'U. R. S. S., p. 438. (Figs. 5, 6, 9 and 10.)

Thanks to the kindness of Doctor Kiritshenko, I possess a female paratype of this species. Aside from the difference mentioned in the key, I cannot distinguish it from *N. triguttata* Motsch. from Japan. It may be that the male shows some specific structural difference. The punctations on the partype in my possession do not clearly separate it from *N. triguttata.* I quote below Doctor Kiritshenko's description and notes:

"♂, ♀. Corpus elongatum, sat angustum, superne et inferne fere totum nigrum. Caput, fronte, viridi excepta, et pronotum superficie superna tota nec non inferne limbis lateralibus sat latis albida. Hemelytra nigra, clavo dimidio basali toto, plaga communi clavi et corii, comissuram clavi occupante et apicem clavi haud attingente, corii plaga propter venam radialem nec non macula parva ad medium suturæ membranæ sita lutescentibus; exocorio margine externo etiam tenuiter lutescenti-limbato, clavo ad dimidium apicalem

marginis scutellaris vitta angusta submarginali arcuata lutescenti, propter comissuram clavi breviter prolongata prædito; membrana et ventre toto nigris, pedibus sordide flavescenti-virescentibus.

"Caput ante oculos late rotundatum, vertice synthlipsi triplo latiore. Pronotum latitudini suæ anticæ aequilongum, latitudine postica duplo brevius, marginibus lateralibus a supero visis subrectis, angulis anticis rectangularibus, superficie superna nitida, tenuiter punctulata; metanotum totum nigrum. Scutellum totum nigrum, opacum, densissime punctatum, apice acuminatum et longe attenuatum, latitudine sua basali paullo brevius. Hemelytra densissime punctata, pilis incumbentibus aureis parce tecta, angulo apicali corii multo densius piloso, comissura clavi margine scutellari aequilonga, lobis membranæ aequalibus et aequilongis. Abdomen supra nigrum, segmentis 4 ultimis margine externo flavescenti-maculatis.

"Long. corporis 13.5-14 mm., long pronoti 2.6-2.8 mm., lat. hemelytrorum 4.4-5.1 mm., lat. synthlipsis 0.7-0.8 mm.

"Habitat in prov. Primorskaja Sibiriæ orientalis: Novokievskoje in litore sinus Posjet (27-28 IX 1928, Prinada leg., Posjet (11 V 1928, Volk leg.).

"Species supra descripta ad sectionem specierum generis orientali-asiaticarum: *N. triguttata* Motsch., *N. chinensis* Fallou, *N. kirkaldyi* Martin, *N. kiangsis* Kirk. pertinet, ex quibus *N. triguttata* Motsch., specie japonica valde affinis et similis, differt statura angustiore et longiore, connexivo, ventre et maxima parte hemelytrorum nigris, hemelytris praecipue clavo et exocorio distinctius punctatis; a *N. kiangsis* Kirk., specie alia ussuriensi, magnitudine majore et latiore, colore, vertice latiore facile cognoscitur."

Notonecta triguttata Motsch. 1861

(Color Plate IV, fig. 4; Plate XV, fig. 6.)

1861. *N. triguttata* Motschulsky, Etudes Ento., x, p. 24.
1897. *N. triguttata* Motsch.; Kirkaldy, Trans. Ento. Soc. London, p. 417.
1904. *N. triguttata* Motsch.; Kirkaldy, Wien. Ento. Zeit., xxiii, p. 95, 132.
1912. *N. triguttata* Motsch.; Oshanin, Katalog der paläarktischen Hemipteren, p. 91.
1925. *N. triguttata* Motsch.; Esaki, Notulæ Entomologicæ, v, p. 14, fig. 2. (Figures head and pronotum.)
1925. *N. triguttata* Motsch.; Hungerford, Annals Ento. Soc. Am., xviii, p. 418. (Notes.)
1928. *N. triguttata* Motsch.; Hutchinson, Ento. Mo. Mag., lxiv, pp. 36, 37. (Figures male genital capsule.)
1929. *N. triguttata* Motsch.; Hutchinson, Annals South African Museum xxv, Pt. 3, p. 363. (Subg. Paranecta.)
1930. *N. triguttata* Motsch.; Kiritshenko, Annuaire du Musée U. R. S. S. Zoölogique de l'Academic des Sciences de l'U. R. S. S., p. 436.

Size. Length, 13-14 mm.; width across thorax, 4.5 mm. to 5.1 mm. The females appear to be larger than the males.

Color. Black and flavous. Head and limbs of usual color; scutellum black; hemelytra black or bluish black with two oblique flavous stripes on basal half and spot on distal margin of corium midway between lateral margins; sometimes the flavous bands are broad and coalesce, again they may be reduced to narrow lines. The general pattern is that of *N. obliqua* Gallén. The venter and the dorsum of abdomen are dark in color.

Structural Characteristics. Head relatively smaller than in *N. chinensis* Fallou; anterior breadth of vertex : synthlipsis : : 13:5; head a little more than half as long as pronotum. Lateral margins of pronotum divergent and but slightly sinuate or incurved, nearly straight, especially in the males; anterior angles of pronotum normal; lateral ledge as seen from the side, faintly sigmoid, the rear end turned up beneath the humeral elevations. Scutellum longer than pronotum. Posterior lobe of membrane a trifle longer than anterior lobe. Anterior trochanter of male with a small dentation instead of a hook; mesotrochanter with angle sharply produced. Terminal abdominal sternite in female notched at tip; female with first pair of gonapophyses short; male gential capsule as shown on Pl. XV, fig. 6.

Location of Type. Kirkaldy wrote "?Moscow." In 1915 Kiritshenko examined Motschulsky's types and reported that there were two specimens, one labeled "Japonia" and one without locality label. They are at Moscow.

Data on Distribution. Japan. Kirkaldy, in his "Uber Notonectiden," adds, "Shantung, China—Distant collection."

Notonecta montandoni Kirkaldy 1897

(Color Plate IV, fig. I; Plate XVII, fig. 6)

1897. *N. montandoni* Kirkaldy, Ann. and Mag. Nat. Hist. (6), xx, p. 56.

1897. *N. montandoni* Kirkaldy, Trans. Ento. Soc. London, 1897, pp. 417, 418.

1904. *N. montandoni* Kirkaldy, Wien. Ento., xxiii, pp. 95 and 132.

1906. *N. montandoni* Kirkaldy; Distant, Faun. Brit. Ind. Rhynchota, vol. iii, p. 41, fig. 25.

1912. *N. montandoni* Kirkaldy; Oshanin, Katalog der paläarktischen Hemipteren, p. 91.

1925. *N. montandoni* Kirkaldy; Hungerford, Annals Ento. Soc. Am., xviii, p. 418 (notes).

1925. *N. montandoni* Kirkaldy; Esaki, Notulæ Entomologiæ, v, p. 13.

1930. *N. montandoni* Kirkaldy; Kiritshenko, Annuaire du Musée Zoölogique de l'Académie des Sciences de l'U. R. S. S., p. 436.

Referring to this species, also:

1905. *N. bivittata* Matsumura, Jl. Sapporo Agric. Coll., vol. ii, p. 59, Pl. 1, fig. 9♀, 1905 (Esaki).

1925. *N. bivittata* Matsumura; Esaki, Notulæ Entomoligiciæ, p. 14, footnote says examined the type and finds it to be *N. montandoni* Kirkaldy.

Size. Length, 15 mm. to 16 mm.; width across prothorax, 5 mm. to 5.5 mm.

Color. Head and limbs of usual color; scutellum black; hemelytra reddish-orange unevenly marked with black, the black figures often coalescing into an irregular transverse band across corium, membrane black with basal part of anterior lobe somewhat mottled with the ground color of the corium.

Structural Characteristics. Head with the anterior breadth of vertex : synthlipsis :: 15:6. Some specimens have synthlipsis a little narrower than above. Head half as long as pronotum. Lateral margins of pronotum divergent and nearly straight, but slightly convex on anterior half; anterior angles normal; lateral ledge, seen from the side, slightly oblique and up-curved beneath the humeral prominence. Scutellum slightly longer than pronotum (6:5). Lobes of hemelytral membrane about equal in length. Anterior trochanter of male without hook or tooth. Mesotrochanter nearly right angulate. Mesofemur with anteapical tooth of usual form. Terminal abdominal sternite of female somewhat constricted near apex, which is not notched. Female gonapophyses of moderate length. Male genital capsule as shown on Plate XVII, fig. 6.

Location of Type. "Montandon collections."

Comparative Notes. This species is a little larger than *N. chinensis* Fallou and has some maculations on basal half of hemelytra. It also has a mesotrochanter that is right angulate instead of acutely angulate as in *N. chinensis* Fallou, *N. triguttata* Motsch., *N. kiangsis* Kirkaldy, and *N. immediata* Kiritch.

Data on Distribution. Given in Kirkaldy's Revision of the Notonectidæ as follows: "China Kiang-Si (Paris Mus.), Ngan-Hoei (Montandon and my collns.), Mou Piu, Tibet. (Paris Mus.)" Paris Museum also has specimens labeled "Museum Paris Kouy-Tchéou, Kouy-Yang, P. P. Cavalerie et Fortunat 1906." The U. S. N. M. has some labeled: "Shin Kai Si, Mt. Omei, Szechuen, China, 4,000-6,000 ft., D. C. Graham, collector"; "Suifu, Szechuen, China, 1920. D. C. Graham Coll."; "4,400 ft. Shin Kai Si Mt. Omei, near Kianting, Szechuen, China, D. C. Graham;" Kiritshenko lists Japan, China and oriental region.

Notonecta pallidula Poisson 1926

(Color Plate V, fig. 2; Plate XVII, fig. 3)

1926. *N pallidula* Poisson, Bull. Soc. Hist. Nat. Afr. Nord, xvii, p. 238, figs. 1 and 2. (Figs. of head and pronotum and genital capsule.)

1928. *N. pallidula* Hutchinson, Ento. Mont. Mag., lxiv, p. 35.

1928. *N. pallidula* Poisson, Bull. Soc. Ento. France, No. 6, pp. 105, 106.

1929. *N. pallidula* Poisson; Hutchinson, Annals of South African Museum, xxv, pt. 3, p. 363.

1933. *N. pallidula* Poisson, Annals de la Soc. Ento. de France, Janvier, 1933.

1933. *N. pallidula* Poisson, Bull. de la Soc. Scien. de Bretagne X, Fasc. III et IV. (Reprint p. 1.)

Referring to this species, also:

1897. *N. glauca* var. *maculata* "leucochroic form" Kirkaldy, Trans. Ento. Soc. London, 1897, pp. 422, 423.

1927. *N. horvathi* Esaki, Ann. & Mag. Nat. Hist. (9), xx, p. 284, figs. 1, 2, 4. (Figs. dorsal view of insect, lateral view of head and thorax and tips of hemelytral membranes.)

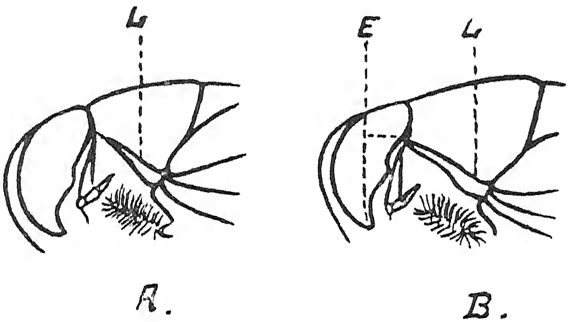
Size. Length, 11.5 mm. to 13 mm.; breadth of pronotum, 4 mm. to 4.5 mm. Females slightly larger than the males.

Color. Body concolorous, pale sordid brown, including scutellum. Irregular obscure dark-brown markings along the costal margin of hemelytra and along the line between corium and clavus. These may be reduced in the male. Metanotum and dorsum of abdomen yellowish with a dark marking on the second, third and fourth and part of the fifth segments. Underside of body black with pale-brown hairs. In some specimens the abdominal venter may be green in color.

Structural Characteristics. Body comparatively stout. Head rather large with large eyes; vertex narrow at base; anterior breadth of vertex : synthlipsis :: 8:3. Pronotum transverse, lateral margins divergent, the lateral ledges more oblique and shorter than in *N. glauca* Linné. Scutellum much shorter than in *N. glauca* Linné and more strongly narrowed toward the apex. Membrane divided into two nearly equal parts along the median longitudinal line, the apex of the basal portion is more angularly and more posteriorly projecting than that of the apical half. Mesotrochanter rounded. The male genital capsule provided with a finger-like projection. The clasper as shown in figure 8, Plate XVII. (See, also, figures 3 and 14.)

Location of Types. The author does not state the depository of the types.

Data on Distribution. Poisson described this species from ma-



TEXT FIGURE 2. A. *Notonecta pallidula* Poisson (= N. horvathi Esaki). B. *Notonecta glauca* Linn. Lateral view of the head and prothorax. L. = lateral ledge of pronotum. E = rear margin of the eye below the lateral ledge of pronotum. Compare lengths of E. & L. in figures A. & B. (Redrawn from Esaki.)

terial taken by M. H. Gauthier in North Africa, who found it living alone in the "oued Reghaia," but in company with *N. maculata* and *N. glauca* in the "oued Safsaf."*

Professor Teiso Esaki, who described this species under the name *N. horvathi,* studied a male and two females from Tangier that were in the National Museum of Natural History, Paris. Esaki says they were determined by Kirkaldy as *N. glauca* var. *maculata*. Poisson belives that Delcourt (1909) had seen this species from Spain, Portugal, Italy and North Africa, but had considered it to be *N. maculata*. Doctor Poisson informs me that Algeria and Morocco are the only records confirmed.

Notonecta canariensis Kirkaldy 1897

Color Plate IV, fig. 8; Plate XVII, fig. 10.)

1897. *N. glauca* var. *canariensis* Kirkaldy, Trans. Ento. Soc. London, 1897, pp. 420, 422 and 423.

1904. *N. glauca* var. *canariensis* Kirkaldy, Wien. Ento. Zeit, xiii, p. 132.

Size. Length, 14 mm. to 15 mm.; width of pronotum, 4.85 mm. to 5 mm.

Color. General color effect dark. Head, thorax and legs dark testaceous; an indefinitely V-shaped dark spot on the pronotum behind the vertex of the head. Femur with more or less definite longitudinal dark stripe. Venter, except the connexivum, nearly black. Scutellum black. Hemelytra brown almost completely submerged by irrorations (often suffused) that are very dark brown or bluish-black; membrane dark brown to bluish-black.

Structural Characteristics. Anterior outline of the head viewed from above flattened; vertex shorter than its anterior width; margin of vertex less convex and longer than the margin of an eye; anterior breadth of vertex : synthlipsis :: 2 + : 1. Pronotum slightly more than twice as long as the head; lateral ledge as seen from the side sigmoid and oblique, shorter than the rear margin of the eye below it. Scutellum longer than the pronotum. The ridge of the hemelytral suture : length of scutellum :: 13:16. Anterior lobe of membrane distinctly longer than the posterior lobe. Anterior trochanter of male with tubercle. Mesotrochanter not angulate. Anteapical tooth of femur large. Terminal abdominal sternite of female with lateral margins not concave and tip not plainly incised. First pair of gonapophyses probably moderately short. Male genital capsule as shown on Plate XVII.

* Oued.—An arabic word signifying running water and which designates more particularly the courses of temporary streams in the Sahara. It becomes a part of the name of a great number of courses of water and localities.

Location of Types. In the Vienna Museum I found four specimens, three males and one female, labeled "O. Simony, 1888 Teneriffa" and, in addition, on one label is written "Barenco Nedalgo." I placed red cotype labels on these specimens, since they are the specimens studied and recorded by Kirkaldy.

Comparative Notes. Kirkaldy in his description wrote: "Notocephalon a trifle narrower than in the other forms. Hemelytra purple-black, obscurely irrorated with dark, rich castaneous, margins of hemielytral areas narrowly the same colour; anterior half of exocorium rich castaneous blotched with black, posterior half black. Membrane black. Pedes rufotestaceous, suffused with rich green."

This sturdy species is closely related to *N. maculata* Fabr. The mesofemural tooth is longer and stouter, the tibia bears a conspicuous elevation. The margin of the pronotum is more strongly ledged, especially on the front half; the abdomen without the orange-yellow band at base. The clasper of the male genital capsule slightly different.

Data on Distributions. The Canary Islands. Besides the cotypes the Vienna Museum has ten specimens labeled "Gomera" "Canar. Ins. Polatzek," and seventeen specimens labeled "Tenerife" "Canar. Ins. Polatzek."

Notonecta maculata Fabricius 1794

(Color Plate V, fig. 10; Plate XVI, fig. 7.)

1794. *N. maculata* Fabricius, Ento. Syst., iv, p. 58.

1799. *N. maculata* Coquebert, Ill. Icon. Ins., p. 38, tab. x, fig. 1.

1803. *N. maculata* Fabricius, Syst. Rhyng., p. 103.

1817. *N. maculata* Leach, Trans. Linn. Soc. London, xii, pt. 1, p. 12.

1824. *N. maculata* Curtis, Brit. Ento. (ed. 1.), I, pl. x. (Esaki says plate is in different volume in later editions.)

1843. *N. glauca* var. *maculata* Amyot et Serville, Hem., p. 453.

1845. *N. maculata* Herrich-Schäffer (fide Curtis) = *marmorea* H. S., Wanz. Ins. viii, p. 23, tab. cclvi, fig. 797.

1848. *N. maculata* Amyot, Ento. Franc, Rhynch., p. 338. (Name invalid.)

1865. *N. maculata* Douglas & Scott, Brit. Hem. I, p. 588.

1888. *N. glauca* var. *maculata* Fabr., Reuter; Synonymica Heteropterorum palaearcticorum *in*: Acta Societatis Scientiarum Fennicæ Tomus XV, p. 727.

1892. *N. glauca* var. *maculata* Saunders, Hem. Heter. Brit. Is., p. 329.

1897. *N. glauca* var. *maculata* Kirkaldy, Rev. d'Ento., xvi, pp. 222, 224.

1897. *N. glauca* var. *maculata* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 422.

1905. *N. glauca* var. *maculata* Hüeber, Jahresh. Ver. Vaterl. Natur. Württemberg, lxi 117.

1909. *N. maculata* Fabricius; Delcourt, Bull. Scientifique Fr. Belg. (7) xliii, p. 378 and pp. 389 and beyond.

1909. *N. glauca* var. *maculata* Oshanin, Verz. Palæ. Hem. I, p. 975.

1910. *N. glauca* var. *maculata* Whittaker, Entomologist, xviii, p. 97. London. (Mating in Jan. near Winscombe, Somerset.)

1922. *N. maculata* Despax, Bull. Soc. Hist. Nat. Toulouse L., 1922, pp. 97-112, 19 figs. (morphology of genitalia.)

1923. *N. glauca* var. *maculata* Lundblad, Ento. Tidsk., 1922-23, p. 72.

1923. *N. maculata* Butler, Biol. Brit. Hem. Heter., p. 579.
1924. *N. maculata* Poisson, Bull. Biol. de France et Belgique, T. lviii (1924), Fasc. 1. (Many ref. and figs.)
1924. *N. maculata* Hale, Proc. Lin. Soc., New South Wales, xlix, pt. 4, p. 462. (Notes.)
1925. *N. maculata* Jaczewski, Ann. Zool. Mus. Polon. Hist. Nat., iv, p. 128, fig. 2.
1926. *maculata* Poisson, Bull. de la Soc. d'Hist. Nat. de l'Afrique du Nord., T. Dix-Septieme, p. 247, Nov., 1926. (Figures, head and protrorax.) (Also, p. 269, Dec., 1926.)
1926. *N. maculata* Fabr.; Poisson, Cpt. rend. Soc. Biol. Paris, Bd. 94, p. 562 and 1007 (Cytology.)
1927. *N. maculata* Fabr.; Poisson, Archives de Zoölogie Experimentale et General. . . . Tome 66, Fasc. 2. pp. 23-70. (Cytological study.)
1928. *N. maculata* Esaki, Annals & Mag. Nat. Hist., Ser. 10 ii, pp. 69, 70, 75.
1929. *N. maculata* Fabr.; Poisson, Bull. Soc. d'Hist. Nat. de l'Afr. du Nord, xx, pp. 112, 113.
1929. *N. maculata* Hutchinson, Annals of South African Mus., vol. xxv, pt. 3, p. 363.
1929. *N. maculata* Lindberg, Soc. Scient. Fennica Comment. Biologicae, iii, 4, pp. 11,12. (Took species in Spain and Morrocco, and says in both flowing and standing water.)
1930. *N. maculata* Larsen, Entomologisk Tidskrift 1930, pp. 219-241 (fig. 2a, chorion of egg.)
1930. *N. maculata* Fabr.; Jones, H. P., *reprint* from The Entomologists Record, Vols. XL-XLII, p. 69.
1933. *N. maculata* Fabr.; Poisson, Annales de la Soc. Ento. de France, Janvier, 1933.
1933. *N. maculata* Fabr., Poisson, Bull. de la Soc. Scien. de Bretagne, X., Fasc. III et IV (Reprint p. 2).

Referring to this species, also:

1800. *N. glauca* Schellenberg, Cimic. Helvet., p. 21, tab. x.
1803. *N. marmorea* Fabricius, Systema Rhyng., p. 103.
1826. *N. variegata* Leach et Risso, Hist. Princ. Prod. Europ. Mérid. (Risso), v, p. 216.
1835. *N. marmorea* Herrich-Schäffer, Nomencl. Ento., I, p. 63. (See Esaki, 1928.)
1840. *N. glauca* var. *marmorea* Blanchard, Hist. Nat. Ins., iii, p. 89.
1851. *N. fabricii* var. *umbrina* Fieber, Abd. Bohm. Gesel. Wis. (5), vii, p. 474.
1861. *N. fabricii* var. *umbrina* Fieber, Eur. Hem., p. 101.
1880. *N. glauca* var. *umbrina* Puton, Synop. Hém. Hétér. France, iii, p. 218.
1881. *N. glauca* var. *umbrina* Puton, Synopsis H m.-Heteroptera France *in*; Memoires de la Société des Sciences de l'Agriculture et des Arts, 4 Série, Tom. ix, p. 122.
1905. *N. glauca* var. *marmorea* Hüeber, Jahresh. Ver. Vaterl. Natur. Württemberg, lxi, p. 116.
1907. *N. umbrina* Delcourt, Comptes Rendus des Séances et Memoires de la Société de Fr. Biologie, lxii, pp. 11-13. (Eggs in October to January on supports.)
1909. *N. marmorea* Kuhlgatz, Süsswasserf. Deutschl. (Brauer), vii, p. 81.

Size. Length, 12.6 mm. to 15.6 mm.; width of pronotum, 4.5 mm. to 5.4 mm., an astonishing variation! My smallest specimen is a male from Jericho, and the largest a female from Oran (Algeria). I have a specimen from Paris that attains the maximum length but not quite the width.

Color. An orange-red or orange-yellow species irrorated with brownish-red and blackish-brown. Anterior half of pronotum, head, limbs and connexivum of usual color, often suffused with green. Scutellum black. Metanotum orange-yellow with a large blackish blotch bordering the basal half of the scutellar margins. First abdominal dorsum orange-yellow, second to fourth black (the fourth narrowly orange-yellow apically) fifth and beyond, orange-yellow.

The hemelytral markings variable, the dark areas often coalescing at the distal inner angle of the corium.

Structural Characteristics. Anterior outline of head, viewed from above, flattened; vertex shorter than its anterior width; margin of vertex less convex and longer than the margin of an eye; anterior breadth of vertex : synthlipsis :: 2 + : 1. Pronotum slightly more than twice as long as the head; lateral ledge, as seen from the side, sigmoid and oblique, shorter than the margin of the eye below it. Scutellum longer than the pronotum. The ridge of the hemelytral suture : length of scutellum :: 13:18—. Anterior lobe of membrane a little longer than the posterior lobe. Anterior trochanter of male with very slight inconspicuous tubercle. Mesotrochanter not angulate. Anteapical tooth of femur of normal size (not large as in *N. canariensis* Kirk.). Terminal abdominal sternite of female with lateral margins slightly concave and tip shallowly incised. First pair of gonapophyses moderately short. Male genital capsule as shown on Plate XVI.

Location of Types. Delcourt says the types are in the Paris Museum.

Comparative Notes. This species differs from other common European species in having a head that is broad and truncate in front, in having a mottled brown color and in having the last ventral abdominal sternite of the female not compressed just before the tip. In this regard it agrees with *N. pallidula* Poisson, from which it is distinguished as shown by Poisson in his description.

Biological Notes. Delcourt, 1907, says this species attaches its eggs to the surface of some support in the water. The egg-laying period is from October to January. By keeping some eggs at a temperature of from 0 to 8 degrees they were held from October to following September. At 18 degrees they hatched in 20 days. Whittaker records the mating on January 14 in Summerset, England.

Data on Distribution. Doctor Poisson has been kind enough to give me the following information: Denmark, Holland, Belgium, England (West and South), Iberian Peninsula, North Africa (Algeria and Morocco), Egypt, Macedonia, Greece, Italy, Corsica, Central Europe, West and Southwest of Persia. My own records include the following: Paris, France; La Galle, Le Boul; Algeria; Phillippeville, Le Boul; Brindisi, J. Sahlb; Egypt, G. Fallou; Sardinia, A. H. Krausse; Morocco, G. Buchet, 1903 (Paris Mus.), Pushire, Persia; Karab, 23, 1931, VII, Alban. Exp. 1918. (Vienna Mus.); Baluchi-

stan. Quetta, Pond in Res. Garden, Sta. No. 3, 11-10-18. B. S.; Shisha R. Pond 6,640 ft., 8 II, 96 Pamir Exp. (Indian Mus.).

Notonecta meinertzhageni Poisson 1934

N. meinertzhageni Poisson, Annals & Mag.. Nat. Hist. (10) xiii p. 170-173 (with text figures).

Size. Length, 15 mm.; width of pronotum, 5.7 mm.*

Color. An orange-red and black species with pattern same as *N. chinensis* Fallou. (See Color Plate IV, fig. 1.)

Structural Characteristics. Anterior outline of head, viewed from above, flattened; the anterior outline of vertex slightly produced medianly; vertex shorter than its anterior width; margin of vertex less convex and about equal to anterior margin of the eye; anterior breadth of vertex : synthlipsis :: 37:17. Pronotum slightly more than twice as long as the head; lateral ledge, as seen from the side, sigmoid and oblique, shorter than the margin of the eye below it; anterolateral angles obtuse. Anterior trochanter of male with very slight inconspicuous tubercle. Mesotrochanter rounded. Male genital capsule resembles that of *N. maculata* Fabr. The clasper has a slight angle or projection on caudal margin. Poisson's drawing shows lateral edge of pronotum straight.

Location of Types. In British Museum and in collection of Doctor Poisson.

Data on Distribution. Described from specimens labeled "Ahaggar Mts., 1931, col. Meinertzhagen."

Notonecta arabiensis Hungerford 1926

(Color Plate V, fig. 1)

1926. *N. arabiensis* Hungerford, Annals Ento. Soc. of Amer., xix, No. 3, p. 280.

Size. Length, 16 mm.; width across the eyes, 4 mm.; width across the thorax, 6 mm.

Shape. Robust.

Color. Head, pronotum, connexivum and limbs yellow. Scutellum black, rear margin of pronotum somewhat darkened. Apical portion of wing membrane dark, remainder of membrane, corium, and clavus brick red with some faint irregular blackish blotches. Venter blackish, midventral keel slightly and abdominal margins plainly yellow.

Structural Characteristics. Head short. Anterior outline of the

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* This short description made from a paratype belonging to thé British Museum.

head, viewed from above, flattened. Vertex considerably shorter than its anterior width, margin of vertex nearly straight, curving at its lateral margins and nearly equal in length to the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 19:10. Pronotum arched and at least three times as long as the head; lateral margins strongly divergent and straight; anterior angles normal; lateral ledge, as seen from the side, slightly sigmoid and oblique and a trifle shorter than the rear margin of the eye below it. Scutellum a little longer than the pronotum or the ridge of the hemelytral suture. Lobes of membrane about equal. Legs stout. Mesotrochanter rounded. Terminal abdominal sternite of female quite large and but slightly constricted before the tip, which is not notched.

Location of Types. Described from two females taken in Arabia and belonging to British Museum. These are designated as holotype and paratype. It is to be hoped that male specimens may be found to enable us to figure the male genital capsule.

Comparative Notes. These specimens are of the same size and color as *N. violacea* Kirkaldy. From this species they differ, however, in having a broader, shorter head, wider synthlipsis, and less flattened lateral margins of pronotum as seen from above. Shorter, blunter mesofemoral tooth. No prominence on caudal margin of mesotibia just distad to femoral tooth when the limb is flexed. *Notonecta violacea* Kirkaldy is provided with one. The last abdominal sternite of female is not conspicuously constricted near its tip as in *N. violacea* Kirkaldy. I have before me Kirkaldy's type, a male from Catcin Cauri, Birmania.

Notonecta violacea Kirkaldy 1897

(Color Plate IV, fig 11; Plate XVII, fig. 11.)

1897. *N. montandoni* Kirk. var. *violacea* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 418.

1904. *N. montandoni* Kirk. var. *violacea* Kirkaldy, Wien. Ento. Zeit, xxiii, p. 132 (lists only).

1915. *N. violacea* Kirk.; Hungerford, Annals Ento. Soc. Am., xviii, p. 418 (notes).

Size. Length, 17.2 mm.; width across pronotum, 6.5-7 mm.

Shape. Large, plump species.

Color. Head, anterior part of pronotum and limbs dark testaceous; front of head and limbs may be greenish; scutellum black; hemelytra including basal two-thirds of anterior lobe of membrane reddish, faint-violet in background, rest of membrane brownish-black. Base of hind wing and marginal vein red.

Structural Characteristics. Anterior breadth of vertex : synthlip-

sis :: 9:3; lateral margins of pronotum nearly straight but faintly sinuate; anterior angles not acute. Scutellum longer than pronotum 7— : 5). Lobes of membrane equal in length. Anterior trochanter of male without hook or dentation. Mesotrochanter rounded (perhaps faintly angulate). Mesofemur with usual anteapical tooth. Mesotibia with denticulate prominence on rear margin. Terminal abdominal sternite of female large and strongly constricted near tip, which is entire. First pair of gonapophyses long. Male genital capsule as shown on Plate XVII, fig. 11.

Location of Types. Described by Kirkaldy as a variety of *N. montandoni* Kirk. He gives the habitat as: "Burma: 'Catein Cauri,'" (Fea Ag. Nov., 1886) and specimens as being in Montandon's, Hamburg Mus. and his own collection. I have found specimens in the Kirkaldy collection at the U. S. N. M. labeled "Catein Cauri Birmania Fea, Ag. Nov., 1886" and determined by Kirkaldy as *N. montandoni* var.

Comparative Notes. Although described as a variety of *N. montandoni*, it is a distinct species which is related to *N. arabiensis* Hungerford and *N. amplifica* Kirit., from which it may be distinguished by the key presented below.

A. Mesotibia with denticulate prominence on rear margin.................... *N. violacea.*
AA. Mesotibia without denticulate prominence on rear margin.
  B. Rear margin of middle tibia at base emarginate and detineulate. Last abdominal sternite of female strongly constricted...................... *N. amplifica.*
  BB. Rear margin of middle tibia at base straight and not denticulate. Last abdominal sternite of female not strongly constricted.................. *N. arabiensis.*

Notonecta glauca glauca Linné 1758

(Color Plate IV, fig. 10; Plate XVII fig. 7.)

1758. *N. glauca* Linné, Syst. Nat., ed. x., p. 439.
1778. *N. glauca* Goeze, Ento. Beytr., ii., p. 166.
1789. *N. glauca* Gmelin, Syst. Nat. (Linné), ed. xiii, p. 2118.
1794. *N. glauca* Fabricius, Ento. Syst., iv, p. 57.
1803. *N. glauca* Fabricius, Syst. Rhyng., p. 102.
1804. *N. glauca* Panzer, Schäfferi Icon. Ins. Ratisbon., Enum. Syst. i., p. 18.
1817. *N. glauca* Leach. Trans. Linn. Soc. London, xii, pt. i., p. 13.
1829. *N. glauca* Fallén, Hem. Svec., p. 177.
1835. *N. glauca* Burmeister, Handb. Ento., ii, p. 190.
1835. *N. glauca* Herrich-Schäffer, Nomencl. Ento. i, p. 63.
1840. *N. glauca* Spinola, Essai Ins. Hem., p. 59.
1840. *N. glauca* Blanchard, Hist. Nat. Ins., iii, p. 88, tab. Hém. i, fig. 2.
1843. *N. glauca* Amyot et Serville, Hém., p. 452.
1845. *N. glauca* Herrich-Schäffer, Wanz. Ins. viii, p. 23.
1860. *N. glauca* Flor, Rhynch. Livl. i, p. 772.
1865. *N. glauca* Douglas et Scott, Brit. Hem. i, p. 587, tab. xx., fig. 4.
1869. *N. glauca* Linné; Stal, Hemiptera Fabriciana, p. 136.
1875. *N. glauca* Regimbart, Ann. Soc. Ento. Fr. (5), pp. 204, 205, pl. IV (oviposition).
1878. *N. glauca* Snellen van Vollenhoven, Hem. Heter. Neerland, p. 317, tab. xx, figs. 2, 2a.
1880. *N. glauca* var. *glauca* Puton, Synop. Hém. Hétér. France, iii, p. 217.

1881. *N. glauca* var. *glauca* Linn. Puton. Synopsis, Hém.-Hétér. France *in*: Memoires de la Société des Sciences de l'Agriculture et des Arts, 4° Série, Tom. ix, p. 121.

1888. *N. glauca* Reuter, Rev. Synomymica Heter. Palaearcticorum ... *in* Acta Soc. Scient. Fennicæ Tom xv, p. 725.

1890. *N. glauca* Pédaschenco, Rev. Sci. Nat. St. Petersb. I, pp. 358-362 (embryology).

1892. *N. glauca* Saunders, Hem. Heter. Brit. Is., p. 329.

1897. *N. glauca* var. *glauca* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 421.

1897. *N. glauca* Linné; Kirkaldy, Rev. Ento. France, XVI, pp. 222-224.

1897. *N. glauca* Linné; Horvath, Rev. Ento. France, 1897, p. 94.

1898. *N. glauca* Linné; Kirkaldy, Ento. Mo. Mag., ix, (2d), p. 173 (oviposition).

1900. *N. glauca* Linné; Puton, Revue D'Entomologie, xviii, p. 80.

1902. *N. glauca* Pantel and de Sinéty, Compt. Rend. Ac. Sc., Paris, cxxxv.

1904. *N. glauca* Linné; Kirkaldy, Wien. Ento. Zeit, xxiii, p. 132.

1905. *N. glauca* Prowazek, Zeitschr. Insbiol., I, p. 63 (migration).

1905. *N. glauca* Hueber, Jahresh. Ver. Vaterl. Naturk. Württemberg, lxi, p. 113.

1906. *N. glauca* Pantel and de Sinéty, La Cellule, xxiii, pp. 87-303, 8 plates (cytology).

1906. *N. glauca* Poulton, Trans. Ento. Soc., 1906, pp. 403-408 (Preying on Donacia).

1907. *N. glauca* Linné; Delcourt, Comptes Rendus des Séances et Memoirs de la Société de Fr. Biologie, lxii, pp. 11-13. (Mates and oviposits in spring time).

1909. *N. glauca* Linné; Delcourt, Comptes Rendus des Séances et Mem. Soc. de Biologie, Paris, lxvi, pp. 589-591.

1909. *N. glauca* Oshanin, Verz. Palæ, Hem. i, p. 974.

1909. *N. glauca* Kuhlgatz, Süsswasserf. Deutschl. (Brauer), vii, p. 79, fig. 68.

1912. *N. glauca* Jensen-Haarup, Danmarks Fauna, xii (Taeger), p. 31, fig. 10.

1912. *N. glauca* Wefelscheid, Zoöl. Jahrb. (Jena), xxxii, pp. 391 and 407.

1912. *N. glauca* Hoppe, Zoöl. Jahrb. Jena Abt. f. allg. Zoöl., xxxi, pp. 189-244, 2, tables (respiration).

1915. *N. glauca* Linné; Wesenberg-Lund., Insektlivet I. Ferske Vande, pp. 118-125.

1916. *N. glauca* Browne, Jl. of Morph, xxvii, p. 123 (Cytology).

1917. *N. glauca* Linné; Hungerford, Ento. News, xxviii, p. 268.

1917. *N. glauca* Linné; Hungerford, Ento. News, xxviii, p. 174.

1918. *N. glauca* Linné; Hungerford, Ento. News, xxix, p. 241, pl. xv, fig. 6 (figures ovipositor).

1919. *N. glauca* Linné; Hungerford, K. U. Sci. Bull., xi, pp. 43, 166, 169, 179, 180, 181, 186, 190, 255, 256, 258, 259, 262, 263, 265.

1919. *N. glauca* Linné; Hungerford, K. U. Sci. Bull., xi, p. 329. (Error in drawing).

1922. *N. glauca* Linné; Lehmann, Zoöl. Jahrb. Jena, xlvi, pp. 121-158, 2 pl. (Biology of).

1922. *N. glauca* Linné; Despax, Bull. Soc. His. Nat. Toulouse, vol. L, pp. 97-112, figs. 7-12 and 17-19. (Male and female genitalia.)

1923. *N. glauca* Linné; Lundblad, Ento. Tidsk., p. 71.

1923. *N. glauca* Linné; Hale, Rec. S. Aust. Mus., ii, No. 3, p. 418.

1923. *N. glauca* Butler, Biol. Brit. Hem. Heter., pp. 558, 559.

1924. *N. glauca* Linné; Poisson, Bull. Biol. de France et Belgique, lviii, pp. 58, 62-65, 69-71, 73-76, 79, 110, 112, 113, 114, 185, 186, 188, 191, 276-278, 290, 295, 298, 300; pl. 1, fig. 1, pl. 3, figs. 3-5.

1925. *N. glauca* Poisson, Bull. Soc. Ento. France, p. 328, fig. 2.

1925. *N. glauca* Linné; Hungerford, Annals Ento. Soc. Am., xviii, p. 418.

1926. *N. glauca* Linné; Poisson, Bull. de la Soc. d'Hist. Nat. de l'Afrique du Nord., vol. xvii, p. 269.

1926. *N. glauca* Kerkis, Revue Russe d'Ento., xx p. 300 (internal sex organs.)

1928. *N. glauca* Linné; Esaki, Annals and Mag. Nat. Hist., ser. 10, vol. II, p. 67.

1929. *N. glauca* Linné; Lindberg, Soc. Scient. Fennica Comment. Biologicae III, 4, p. 11 (Spain).

1929. *N. glauca* Linné; Hutchinson, Annals of South African Mus., xxv, pt. 3, p. 363.

1930. *N. glauca* Linné; Larsen, Ento. Tidsk., 1930, p. 219.

1930. *N. glauca* Linné; Jones *in* Reprint from The Entomologists Record, vols. XL-XLII, p. 69.

1933. *N. glauca glauca* Linné; Poisson, Annales de la Soc. Ento. de France. Janvier, 1933.

1933. *N. glauca glauca* Linné; Poisson, Bull. de la Soc. Scien. de Bretagne X. (Reprint p. 2.)

Referring to this species, also:

1766. *N. prima* Schäffer, Icon. Ins. Ratisb, I, pt. 1, tab. xxxiii, figs. 5 and 6. (Esaki says name "invalidum et nudum.")

1848. *N.* var. *glauca* Amyot, Ento. France, Rhynch, p. 337, tab. iii, fig. 54. (Esaki says "nom. invalidum.")

1851. *N. fabricii* var *glauca* Fieber, Abh. Bohm. Gesel. Wis. (5), vii, p. 474. (= Rhynchotographien).

Size. Length, 14 mm. to 16 mm.; width of thorax, 4.8 mm. to 5.1 mm.

Color. Typically yellowish-brown with black scutellum and brownish-black maculations along the costal margin of the hemelytra; venter and abdominal dorsum more or less dark.

Structural Characteristics. Head moderately convex, vertex shorter than its anterior width; margin of vertex less convex than margin of the eye; margin of vertex nearly as long as frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 2:1; head less than half as long as pronotum. Pronotum with lateral margins moderately divergent and slightly concave, more so in female than in the male; anterior angles normal; lateral ledge, as seen from the side, sigmoid, caudal end turned up beneath the humeral angle, which is not prominent, somewhat oblique and as long as the rear margin of the eye below it. Scutellum longer than pronotum. Anterior lobe of membrane longer than the posterior. Anterior trochanter of male with slight protuberance. Mesotrochanter rounded. Terminal abdominal sternite of female constricted near the tip, which is bluntly pointed. First pair of gonapophyses of female moderately long. Male genital capsule as shown on plate XVII, fig. 7.

Location of Type. Kirkaldy gives the location of the type "? Upsala." I did not find it there. I found, however, a female, in the Linnean Society's collection in London. Delcourt [22] reported the type as being in London.

Discussion. This species name has been applied to so many forms that one must take the references with some reservation. Kirkaldy placed as varieties of this species the following: *N. marginata* Müller, *N. canariensis* Kirk., *N. marmorea* Fabr. and *N. maculata* Fabr. I have examined most of the material mentioned by Doctor Kirkaldy in his "Revision of the Notonectidæ" and feel that his conception of this species was quite confused. Doctor Delcourt and others have attempted to clear up the specific relationships of the European forms.

Under "*Notonecta* var. 1 *glauca* L.," Kirkaldy included specimens from brackish water near Gravesend (England). These specimens

belong to *N. viridis* Delcourt. The specimens in the Kirkaldy collection bearing the label Gravesend are certainly Delcourt's species.

Doctor Kirkaldy, under this variety (p. 421 of his Revision), says: "From Maie-Nousky, Erzerum (Vienna Mus.) I have seen two specimens resembling in color and disposition of the apical hemielytral fascia, the typical form of *N. americana* Fabr." I have these two specimens before me; they are from Mali, not "Maie," and I have seen eight more in the Vienna Museum. They are, it seems to me, a little larger than typical *N. glauca* Linné. The broad, black band across the hemelytra is a striking characteristic of all of them. (See Color Plate V, fig. 3.) A specimen like these labeled "Monts Baktyaris, 1500 a 4500 m. J. de Morgan 1904" is in the Paris Museum.*

Data on Distribution. Since Doctor Kirkaldy's conception of this species was rather vague, his idea of distribution is not acceptable. Doctor Poisson has been kind enough to write me concerning his knowledge of this species. He says it is widely distributed over Europe and is common in France, but that its southern distribution should be more precisely ascertained. This, I think, applies also to the Asiatic records. The specimens in our own collection came from England, France, Finland and Germany.

Biological Notes. This species has been studied by various European workers. Regimbart,[72] 1875, reported that the eggs are inserted in the stems of aquatic plants. Wesenberg-Lund [84] says the eggs are inserted in plant tissues, air filled, not water-soaked plant parts. He further says that eggs laid in April and May are hatched in the course of three to six weeks. The nymphs pass through five moults, and after five or six weeks they are fully developed. Mating has been observed in late summer, but the usual time is early spring. These insects are good fliers and in the fall seek ponds rich in plant life and overwinter there as adults. Delcourt [22] has reared this species and studied the results of crosses of forms of different color patterns.

Notonecta glauca poissoni new subsp.

(Color Plate V, fig. 3)

This form is larger than the average *N. glauca glauca* Linn. and has a large transverse band across the hemelytra, as shown in the colored figure. Doctor Kirkaldy mentions specimens belonging to the Vienna Museum (see his Revision, p. 421) that came from Mali-Nousky, Erzerum, and says "they resemble in color and dis-

* I have named these *N. Glauca poissoni.*

position of the apical hemielytral fascia the typical form of *N. americana* Fabr." The two specimens mentioned by Kirkaldy are before me. I have seen eight more in Vienna. Paris Museum has a specimen labeled "Monts Baktyaris, 1500 a 4500 m. J. de Morgan 1904."

I propose to make the series in Vienna the types and will mark the holotype, allotype and paratypes.

Notonecta glauca hybrida Poisson* 1933

1933. *N. glauca hybrida* Poisson, Annales de la Soc. Ento. de France, Janvier, 1933.
1933. *N. glauca hybrida* Poisson, Bull. de la Soc. Scien. de Bretagne X, Fasc. III et IV. (Reprint, p. 2.)

This subspecies is, in color, intermediate between *N. glauca* Linn. and *N. maculata* Fabr. The hemelytra are reddish or brownish, more or less strongly maculated, presenting at the base either one pale longitudinal band on the clavus or two bands, one on clavus and the other on the corium. Structurally this form is like *N. glauca* Linn. and the females may be placed at once by examining the last abdominal sternite, which is strongly constricted before the tip, a character like *N. glauca* Linn. and not like *N. maculata* Fabr. Doctor Poisson gives the distribution as Southern France, Iberian Peninsula and North Africa. I have two species sent me by Doctor Poisson. One is labeled "Banyuls" and the other "Pouade."

Notonecta glauca fulva de la Fuente 1898

(Color Plate V, fig. 11; Plate XVI, fig. 6.)

1898. *N. glauca* var. *fulva*, de la Fuente, Actas Esp. Hist. Nat., xxvi, p. 130.
1927. *N. maculata* var. *fulva*, Hutchinson, Annals & Mag. Nat. Hist. (9), xix, p. 375.
1928. *N. glauca* var. *fulva*, Poisson, Bull. Soc. Ento. France, No. 6, p. 106.
1928. *N. maculata* var. *fulva*, Hutchinson, Ento. Mont. Mag., lxiv, p. 35.
1928. *N. maculata* var. *fulva*, Esaki, Annals & Mag. Nat. Hist. (Ser. 10), vol. ii, pp. 70 and 75.

J. M. de la Fuente, in a paper entitled "Datos para la fauna de la provincia de Cindadreal *in Actas* of the "Anales de la Sociedad Española de Historia Natural, 1897, p. 130," described this variety as follows: "*Notonecta glauca* L. v. *fulva:* Elytra fulva, sine maculis, una tantum levissima excepta in basi suture locata."

The type of this variety has not been reëxamined since it was described, and I do not know its location. It has been assumed by Hutchinson that it is an immaculate variety of *N. maculata* Fabr. Mr. Hutchinson says there are specimens from Naples and Southern Tunisia that fit Fuente's *fulva* and which are a variety of *N.*

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* This may be *N. octopunctata* Goeze, 1878, Ento. Beytr., ii, p. 169. See Esaki, Annals and Mag. Nat. Hist. (Ser. 10), vol. ii, p. 76, for comment on *N. secunda* Schäffer.

maculata Fabr. and not *N. pallidula* Poisson. Esaki reports specimens taken by W. E. China in Guernsey, Channel Islands, August, 1927, that should be assigned to *N. maculata* var. *fulva* Fuente.

Mr. China, in 1928, gave me seventeen specimens labeled "Guernsey, August, 1927, W. E. China." All but one of these are typical *N. maculata* Fabr. There is one male, however, that I have taken to be *N. maculata fulva* Fuente, and figured in Color Plate V. This specimen, besides having a little differently shaped head and straighter lateral margins of prothorax, has the dorsum of the abdomen black (lacking the orange band characteristic of all the other specimens) and the anteapical tooth of middle femur small. I have no female specimens from Guernsey. An examination of the last abdominal sternite* of female would show at once whether this form should be assigned as subspecies of *N. maculata* Fabr., as Hutchinson and Esaki assume, or to *N. glauca* Linn., as Poisson believes. Doctor Poisson has recently written me that he has attempted to locate Fuente's type without success and considers the specimens from Guernsey as belonging to *N. glauca rufescens* Poisson. It is in deference to his opinion that I transfer Fuente's species to *N. glauca fulva*, but strongly suspect that *N. glauca rufescens* Poisson will prove to be *N. glauca fulva* Fuente.

Notonecta glauca rufescens Poisson 1933

(Color Plate V, fig. 11.)

1933. *N. glauca rufescens* Poisson, Annales de la Soc. Ento. de France. Janvier, 1933.

1933. *N. glauca rufescens* Poisson, Bull. de la Soc. Scien. de Bretagne X, Fasc. III et IV, 1933. (Reprint, p. 3.)

This subspecies has the structural characters of *N. glauca* Linn. and is distinguished by the almost immaculate reddish hemelytra (see key to species). Since *N. glauca fulva* Fuente must have a similar appearance it may be the same thing. Doctor Poisson has most kindly sent me specimens from Banyuls and Salses.

Notonecta obliqua obliqua Gallén 1787

(Color Plate IV, fig. 6; Plate XVII, fig. 9)

1787. *N. obliqua* Gallén, Mus. Nat. Acad. Upsal., pt. v, p. 61 (Esaki).

1897. *N. obliqua* Thunb.; Kirkaldy, Trans. Ento. Soc. London, p. 419. (According to Esaki, Kirkaldy credited wrong author.)

1928. *N. obliqua* var. *obliqua* Esaki, Ann. & Mag. Nat. Hist., ser. 10, vol. ii, p. 68.

1929. *N. obliqua* var. *obliqua* Hutchinson, Ann. South African Museum, XXV, pt. 3, p. 363.

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* I have asked Mr. China, of the British Museum, to examine the females from Guernsey with reference to this point. He replies: "No females are present."

1933. *N. obliqua* Gallén; Poisson, Annales de la Soc. Ento. de France. Janvier, 1933.

1933. *N. obliqua obliqua* Gallén; Poisson, Bull. de la Soc. Scien. de Bretagne X, Fasc. III et IV (Reprint p. 3). (Also, Fasc. I et II, Reprint, p. 29, egg of).

Referring to this species, also:

1794. *N. furcata* Fabricius, Ento. Syst., iv, p. 58.

1799. *N. furcata* Coquebert, Ill. Icon. Ins., p. 38, tab. x, fig. 2.

1803. *N. furcata* Fabricious, Syst. Rhyng., p. 102.

1807. *N. furcata* Haworth, Trans. Ento. Soc. London, i, p. 98.

1817. *N. furcata* Leach, Trans. Linn. Soc. London, xii, pt. 1, p. 12.

1826. *N. melanota* Leach and Risso, Hist. Princ. Prod. Eur. Mérid. (Risso), v, p. 215 (Esaki).

1829. *N. furcata* Fallén, Hem. Svec., p. 178.

1835. *N. glauca* var. *a* Burmeister, Handb. Ento., ii, p. 190.

1835. *N. furcata* Herrich-Schäffer, Nomencl. Ent., i, p. 63.

1840. *N. fuscata* (!) Spinola, Essai, Ins. Hem., p. 59.

1840. *N. glauca* var. *furcata* Blanchard, Hist. Nat. Ins., iii, p. 89.

1843. *N. glauca* var. *furcata* Amyot et Serville, Hem., p. 453.

1845. (sine nom.) Herrich-Schäffer, Wanz. Ins., viii, p. 24, No. 4.

1848. *N.* var. *furcata* Amyot, Ento. Franc., Rhynch. p. 337, nom. invalid.

1851. *N. fabricii* var. *furcata* Fieber, Abh. Böhm. Gesel. Wis. (5), vii., p. 474.

1861. *N. fabricii* var. *furcata* Fieber, Eur. Hem., p. 101.

1865. *N. glauca* var. *furcata* Douglas et Scott, Brit. Hem., i, p. 588.

1880. *N. glauca* var. *furcata* Puton, Synop. Hém. Hétér. France, iii, p. 217.

1881. *N. glauca* var. *furcata* Fabr.; Puton, Synopsis Hém. Hétér. France *in*: Memoires de la Société des Science de l'Agriculture et des Arts, 4° Série, Tom. IX, p. 121.

1888. *N. glauca* var. *furcata* Reuter, Syn. Heterop. palæarcticorum *in*: Acta Soc. Scient. Fennicæ, Tomus XV, p. 727.

1892. *N. glauca* var. *furcata* Saunders, Hém. Hétér. Brit. Is., p. 329, tab. xxxi, fig. 2.

1897. *N. glauca* var. *marginata* Müller; Kirkaldy, Trans. Ento. Soc. London, 1897, p. 421 (Esaki says name applied to a corixid).

1904. *N. fabricii* var. *fasciata* (!), Kirkaldy ("fide Fieber, 1861"), Wien. Ent. Zeit., xxiii, pp. 95, 132.

1905. *N. glauca* var. *furcata* Hueber, Jahresh. Ver. Vaterl. Naturk. Württemberg, lxi, p. 117.

1906. *N. glauca* var. *marginata* Distant, Faun. Brit. Ind., Rhynch. iii, p. 41.

1907. *N. furcata* Fabr.; Delcourt, Comptes Rendus des Seances et Memoires de la Société de Fr. Biologie, lxii, pp. 11-13.

1909. *N. furcata* Fabr.; Delcourt, Bull. Scient. Fr. et Belge, xliii, pp. 373, 461 (numerous references).

1909. *N. glauca* var. *furcata* Oshanin, Verz. Palæ. Hém., i, p. 975.

1909. *N. glauca* var. *furcata* Kuhlgatz, Süsswasserf. Deutschl. (Brauer), vii, p. 81.

1915. *N. glauca* var. *furcata* Fabr.; Bollweg, Verhandlungen des Naturhistorischen Vereins der Preussischen Rheinlande und Westfalens 71. Jahrgang 1914, p. 174.

1922. *N. glauca* var. *furcata* Fabr.; Despax, Bull. Soc. Hist. Nat. Toulouse 1922, pp. 97-112.

1923. *N. glauca* var. *furcata* Fabr.; Lundblad, Ento. Tidskrift 1922-1923, p. 72.

1923. *N. furcata* Butler, Biol. Brit. Hém. Hétér., p. 559.

1929. *N. furcata* Hutchinson, Annals of South African Museum, xxv, pt. 3, p. 363.

1930. *N. furcata* Jones, *in* Reprint from the Entomologists Record, XL-XLII, p. 69.

1930. *N. furcata* Larsen, Entomologisk Tidskrift, 1930, pp. 219-221.

Size. Length, 16 mm.; width of pronotum, 5.1 mm. to 5.4 mm. A large species that may vary both ways from above measurements.

Color. A black and luteous species. Head and limbs of usual color; scutellum black; hemelytra black or blue-black with two oblique luteous stripes on basal half; hemelytral suture pale; venter and abdominal dorsum dark.

Structural Characteristics. Head not prominent. Anterior outline of head moderately convex; vertex shorter than anterior width; margin of vertex less convex than margin of the eye; margin of vertex longer than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 2:1. Pronotum more than twice as long as the head; lateral margins moderately divergent and slightly concave; anterior angles normal; lateral ledge, as seen from the side, slightly sigmoid, nearly horizontal and longer than rear margin of eye below it. Scutellum longer than the pronotum. Anterior lobe of membrane slightly longer than posterior. Anterior trochanter of male with slight elevation that is obscured by a more or less dense pilosity. Mesotrochanter rounded. Terminal abdominal sternite of female large, constricted near the tip, which is bluntly pointed. First pair of gonapophyses moderately long.

Location of Type. Unknown to me. I did not see it in the Museum at Upsala. Delcourt reports type of *N. furcata* Fabr. to be in Paris.

Discussion. This species is better known under the names *N. furcata* Fabr.; *N. marginata* Müller, or treated as a variety of *N. glauca* Linn. Doctor Esaki, 1928, says, "Kirkaldy identified this species, *Notonecta furcata*, auct., with *Notonecta marginata* Müller." Müller writes: "*N. marginata* elytris nigris: margine suturaque luteis" [Zoöl. Dan. Prodr. p. 104 (1776)]. This description does not agree with this species, and although "*furcata*" is mentioned by Jensen-Haarup in Danmarks Fauna, I have no verification of its occurrence; in any case it is not a common form in Denmark, so that I do not agree with Kirkaldy's opinion. On the other hand, *marginata*, Müller, is most probably identical with one of the *Corixa* (sensu lat.) species, as the description covers all the forms which are common in Denmark, and *marginata* was placed by Müller between *Notonecta striata* and *N. minutissima*, both of which are Corixids. The British Museum copy of Müller's work originally belonged to J. C. Schiödte, the well-known Danish hemipterist, and among his annotations he writes of *Notonecta marginata* "= *Corixa hellensi*, Fallén, 183," so that there is little doubt as to the generic identity of Müller's species."

Doctor Esaki, 1928, also says: "The name *obliqua* was referred to "Thunberg DD. Ac. Mus. Upsal., p. 61" by Kirkaldy. The correct title of this book is: "Museum Naturalium Academiæ Upsaliensis (præside C. P. Thunberg)," and different parts were worked out by different authors. Part V (pp. 59-68), "Donation Thunbergianæ

1785, Continuat. III," in which this species is included, was written by Olavus Gallén, not by Thunberg, and was published in 1787 (according to Hagen, Bibl. Ent., on December 5). His description is as follows: "Hemelytra nigris lineis duabus obliquis abbreviatis cinereis." This agrees quite well with *Notonecta furcata* Fabricius, and therefore I have synonymized the latter with *N. obliqua* Gallén. While Delcourt[22] found all color pattern gradations between this species and *N. glauca* Linn., and Despax[24] concludes that it is only a variety of *N. glauca* Linn., I am retaining them as distinct though closely related species and await the conclusions of Doctor Poisson, who has at his command much material and the advantage of recent morphological studies.

Data on Distribution. Northern and middle palæarctic. Doctor Poisson writes me that it is to be found in the east, north, northwest, west and central France, and that most typical form appears to be that from Normandy.

*Notonecta obliqua delcourti** Poisson 1933

1933. *N. obliqua delcourti* Poisson, Annales de la Soc. Ento. de France. Janvier, 1933.
1933. *N. obliqua delcourti* Poisson, Bull. de la Soc. Scien. de Bretagne X, Fasc. III et IV. (Reprint, p. 3.)

This variety, Doctor Poisson says, is distinguished from *N. obliqua obliqua* Gallén by having in addition to the two typical bands on the hemelytra a large flavous spot beyond the corial band. I have not seen this variety.

Notonecta obliqua meridionalis Poisson 1926

(Color Plate V, fig. 5; Plate XVI, fig. 5)

1926. *N. furcata* Fabr. var. *meridionalis* Poisson, Bull. Soc. Hist. Nat. Afrique Nord, xvii, p. 240, November, 1926. (also p. 269, December).
1928. *N. furcata* Fabr. var. *meridionalis* Poisson, Bull. Soc. Ento. France, No. 6, p. 106.
1928. *N. obliqua* Gallén var. *meridionalis* Poisson; Esaki, Annals and Mag. Nat. Hist., ser. 10, vol. ii, p. 69.
1929. *N. obliqua* Gallén var. *meridionalis* Poisson; Hutchinson, Annals South African Museum, xxv, part 3, p. 363.
1933. *N. obliqua meridionalis* Poisson, Annales de la Soc. Ento. de France, Janvier, 1933.
1933. *N. obliqua meridionalis* Poisson, Bull, de la Soc. Scien. de Bretagne X, Fasc. III and IV. (Reprint, p. 3.)

Referring to this species, also:

1897. *N. marginata* Kirkaldy, Trans. Ento. Soc. London, p. 421 (Sind Valley, Kashmir).
1925. *N. furcata* Poisson, Bull. Soc. Ento. France, p. 270.
1925. N. *furcata* Poisson, Bull. Soc. Ento. France, p. 328, fig. 3.

Size. Length, 13.2 mm. to 15 mm.; width of pronotum, 4.8 mm. to 5.4 mm.

* Poisson describes as a variety, not a subspecies.

Color. General facies darker than *N. obliqua* Gallén. Hemelytra nearly black except for a broad flavous line on the basal half of clavus. Some specimens may show a small flavous stripe or some maculations on the corium.

Structural Characteristics. While I cannot fix upon any very good external characters to separate this from *N. obliqua* Gallén, the lateral margins of the pronotum seem straighter and more divergent and as viewed from the side the pronotum more elevated in the rear. The claspers of the two males I have examined differ from those of *N. obliqua* as indicated on Plate XVI.

Location of Type. Not indicated in Poisson's description.

Comparative Notes. In naming this variety Doctor Poisson says that it is a little smaller than the typical *N. obliqua* Gallén and usually only presents one flavous line on the hemelytron, this is on the clavus. In *N. obliqua* Gallén there are two slightly diverging longitudinal flavous lines on the base of the dark hemelytra, one on the corium and the other on the clavus.

Data on Distribution. Doctor Poisson writes me that this species is around the Mediterranean region. Southern France, Iberian Peninsula, North Africa, Asia Minor, Greece, Macedonia, Albania and Italy. I have specimens before me labeled as follows: Tunisia, Tabarca and Ain Draham (Budapest Mus.); Sind Valley, Kashmir Det. by Kirkaldy as *N. glauca* L.; Mor. Sidi Dris de Barein G. Buchet 1903 (Paris Mus.); Constantine, J. Sahlb. Det. by Kirkaldy as *N. glauca* var. *marginata* Müll.; Zaguan, J. Sahlb.; Philippeville, Algerie, A. Thery.

Notonecta amplifica Kiritshenko 1930

(Color Plate V, fig. 4; Plate XVI, fig. 4)

1930. *N. amplifica* Kiritshenko, Annuaire du Musée Zoölogique de l'Academie des Sciences de l'U. R. S. S., 1930, pp. 434 and desc. on pp. 437-438, figs. 1, 2, 3, 4.

Size. Length, 17 mm. to 18.3 mm.; width across thorax, 6 mm. to 6.3 mm.

Shape. Robust.

Color. Head, pronotum, limbs and connexivum dark testaceous. Rear half of pronotum darkened by black beneath. Scutellum with basal two-thirds black mottled with pale yellowish spots. Tip pale. Hemelytra pale brown.

Structural Characteristics. Male head a little broader than that of female; anterior margin of vertex : synthlipsis : : 9 : 4.1. Pronotum somewhat arched, lateral margins slightly sinuate. Scutellum

and elytral suture about equal in length. Anterior lobe of membrane very slightly longer than posterior. Anterior trochanter of male without hook or marked dentation. Middle leg as in *N. arabiensis*, but distal femoral tooth stouter and rear margin of tibia slightly emarginate and minutely denticulate. Terminal abdominal sternite of female strongly constricted. Male genital capsule as shown on Plate XVI, fig. 4.

Location of Types. Described from southeastern Siberia. Types in Petrograd; paratypes in University of Kansas Collection.

Comparative Notes. A large robust species related to *N. violacea* Kirkaldy and *N. arabiensis* Hungerford, see key under *N. violacea* Kirkaldy. Three specimens more slender and of luteous color from "Amur," in British Museum, were labeled by Doctor Kiritshenko as *N. lutea* var. *scutellaris.* The male genitalia shows them to be *N. amplifica* Kiritshenko.

Notes on Distribution. "Habitat in prov. Primorskaja Sibiriæ Orientalis: haud procul a Vladivostok (Sedanka, Tshernaja Rjetshka, Okeanskaja) et Novakievskoje in litore sinus Posjet. (27-27 ix 1928, Prinada leg.)"

Doctor Kiritshenko was kind enough to send me two specimens from Vladivostok.

Notonecta lutea Müller 1776

(Color Plate IV, fig. 7; Plate XVII, fig. 2)

1776. *N. lutea* Müller, Zoöl. Dan Prodr., p. 103.
1778. *N. lutea* Müller; Goeze, Ento. Beytr., II, p. 170.
1804. *N. lutea* Müller; Weber and Mohr, Naturh. Reise de. Schwed., p. 66 (Fieber).
1814. *N. lutea* Müller; Fallén, Hydroc. Nauc. Suec., p. 6 (Van Duzee).
1829. *N. lutea* Müller; Fallén, Hem. Svec., p. 178.
1851. *N. lutea* Müller; Fieber, Abh. Böhm. Gesel. Wiss. (5), vii, p. 473.
1860. *N. lutea* Müller; Flor, Rhynch. Livl., 1, p. 774.
1861. *N. lutea* Müller; Fieber, Eur. Hem., p. 100.
1875. *N. lutea* Müller; Sahlberg, Not. Sällsk. Fauna Fenn. Förh., xiv, p. 274 (Kirkaldy).
1879. *N. lutea* Müller; Puton, Synop. Heter, Fr., p. 218. (From Van Duzee, pagination of Separate.)
1881. *N. lutea* Müller; Puton, Synopsis des Hemipt.-Heteropt. de France 3° Partie. Memoires de la Société des Sciences de l'Agri. et des Arts de Lille, 4° Série, Tome ix, p. 122.
1888. *N. lutea* Müller; Reuter, Rev. Synom., p. 374, No. 351. (From Van Duzee—Pagination of Separate.)
1888. *N. lutea* Müller; Reuter, Revisio Synonymica Heteropterorum Palæarcticorum . . . *in:* Acta Societatis Scientiarum Fennicæ, Tom. XV, p. 728.
1891. *N. lutea* Müller; Duda, Klub. prírod. Praze, p. 13, pl. iv, fig. 1. (Kirkaldy).
1897. *N. lutea* Müller; Kirkaldy, Trans. Ento. Soc. London, 1897, p. 425.
1905. *N. lutea* Müller; Hueber, Jahresh. Ver. Vaterl. Naturk. Württemberg, lxi, p. 118.
1909. *N. lutea* Müller; Oshanin, Verz. Palæ. Hem., I, p. 976.
1909. *N. lutea* Müller; Kuhlgatz, Süsswasserf. Deutschl. (Brauer) VII, p. 82.
1912. *N. lutea* Müller; Jensen-Harrup, Danmarks Fauna, xii (Tæger), p. 31.
1912. *N. lutea* Müller; Oshanin, Katalog der Paläarktischen Hemipteren, p. 91.
1916. *N. lutea* Müller; Lundblad. Ento. Tidsk., p. 220.

1922. *N. lutea* Müller; Lundblad. Ento. Tidsk., p. 73.

1923. *N. lutea* Müller; Bueno & Hussey, Bull. Brooklyn Ento. Soc., xviii, p. 106.

1924. *N. lutea* Müller; Hale, Proc. Lin. Soc. New South Wales, vol. xlix, pt. 4, p. 462. (Notes concerning.)

1925. *N. lutea* Müller; Schmidt, Jahrb. des Nassauischen Veriens für Naturkunde, Jahrgang 77, p. 78 ("neu für die Rheinprovinz").

1928. *N. lutea* Müller; Hutchinson, Ento. Mo. Mag., lxiv, p. 35, 36. (Figs. genital capsule).

1929. *N. lutea* Müller; Hutchinson, Annals of South African Museum, xxv, pt. 3, p. 363.

Referring to this species, also:

1835. *N. unicolor* Herrich-Schäffer, Nomencl. Ento., 1, p. 63.

1845. *N. unicolor* Herrich-Schäffer, Wanz. Ins., viii, p. 23.

1851. *N. tumida* Germar Ms., Fieber mentions in his Rhynchotographieen, p. 473.

Size. Length, 14-16 mm.; width of pronotum, 4.8-5 mm.

Shape. Fairly plump-bodied insects.

Color. Typical color is luteous with brown ventor and legs of intermediate color. The costal margin of hemelytra often brown. Rarely there may occur melanistic specimens having black scutellum and dark hemelytra.

Structural Characteristics. Anterior outline of head, viewed from above, flattened; vertex shorter than its anterior width; anterior margin of vertex less convex than the margin of an eye; anterior breadth of vertex : synthlipsis :: 2.2 ± : 1. Pronotum at least twice as long as the head as seen from above; lateral margins of pronotum concave and only moderately divergent; anterior angles slightly produced, blunt; lateral ledge as seen from the side nearly straight, but slightly oblique, and subequal in length to the rear margin of the eye below it. Scutellum subequal in length to the pronotum. Ridge of hemelytral suture longer than scutellum. Anterior lobe of membrane longer than posterior one. Anterior trochanter of male with hook; mesotrachanter rounded, middle femur with a long stout anteapical tooth. Terminal abdominal sternite of female broad, somewhat constricted before the tip, which is blunt. First pair of gonapophyses in the female stout, broad and moderately long. The male genital capsule with short digitate process and clasper as shown on Plate XVII, fig. 2.

Location of Type. Kirkaldy reports that the type has been lost. The species, however, is well known.

Comparative Notes. This large pale species has its counterpart in *N. borealis* Bueno and Hussey of Northern North America which, for a long time, was confused with the European species and led to the erroneous record of "Nearctic" in Oshanin's catalogue. It is, however, structurally different from the American species, as shown by a study of the genitalia of both sexes. It is also specifically

different from the species named *N. lutea* var. *scutellaris* by Reuter (see Plate XVII, figures 1 and 2.

Data on Distribution. This is a northern species. Reported by Oshanin in his catalogue as present in middle and northern Europe, Crimea and Siberia. Schmidt has reported it from the Rhine province, and I have specimens taken by Dr. O. Lundblad in Sweden; by H. Lindberg, in Finland; and others from Bohemia and Kossau. Doctor Poisson has kindly written me that this species is found in the northern part of eastern and central Europe, its western limits passing from Hanover southward through Alsace, the Jura and the Alps. He reports finding this species at one place, however, farther west (Lác d'Estivadoux near Besse in the department Puy-de-Dôme, France). From the map before me this appears to be in the Auvergne mountain district. Since the specimens from this place in France are structurally like *N. reuteri* Hungerford instead of like what I believe to be *N. lutea Müller*, the distributional records of these two species must be reviewed by the reëxamination of all available material.

Biological Notes. Delcourt,[22] 1909, gives considerable information about the distribution of this species and reports upon catches he has made. In collecting at Ulm, on August 25, 1907, he discovered that this species was fully developed sexually, while *N. glauca* L. was plainly of the new generation. Wesenberg-Lund,[84] 1915, reports that *N. lutea* Müller inserts its eggs into the tissues of plants and winters in the egg stage, its young hatching in the spring along with those of *N. glauca* L. While the egg stage of the latter lasts from four to six weeks, that of *N. lutea* Müller from eight to nine months.

Notonecta lutea Müller var. *schumacheri*, Schirmer, 1911

1911. *N. lutea* Müller var. *schumacheri*, Schirmer, Deutsch. Ento. Zeit., p. 680.
1912. *N. lutea* Müller var. *schumacheri*, Schirmer; Oshanin, Katalog der paläarkt. Hem., p. 91.
1928. *N. lutea* var. *schumacheri*, Schirmer; Esaki, Annals and Mag. Nat. Hist. (10), II, p. 71.

Mr. Schumacher describes this variety as follows:

"Var. *schumacheri* Schirmer nov. In Grösse und Form der Stammart gleich, aber ganz Schwarz, nur der Kopf, das Pronotum und ein schmaler Flügelseitenrand gelb. Diese aufällige Varietät erlaube ich mir dem äusserst strebsamen jungen Forscher auf dem stiefmütterlich behandelten Gebiete der Rhynchoten, Herren F. Schumacher, zu widmen. In 2 Ex. wurde diese Varietät von mir mit der Stammform zusammen gefangen."

I do not agree that this should receive a varietal name. It is, no

doubt, nothing more than an example of melanchroism in *N. lutea* Müller, such as I described in *N. borealis* Bueno and Hussey (1928).

Notonecta reuteri Hungerford 1928

(Color Plate IV, fig. 9; Plate XVII, fig. 1.)

1928. *N. lutea* Müller var. *reuteri* Hungerford, Bull. Brooklyn Ento. Soc., xxiii, June, 1928, No. 3, p. 128. (New name for *N. lutea* var. *scutellaris* Reuter, 1886, which was preoccupied by *N. variabilis* var. *scutellaris* Fieber 1851.)

Referring to this species, also:

1886. *N. lutea* Müller var. *scutellaris* Reuter, Medd. Soc. Faun. Flor. Fenn., xiii, p. 234.

1897. *N. lutea* Müller var. *scutellaris* Kirkaldy, Trans. Ento Soc. London, 1897, p. 425 (credits variety name to "Sahlb. S.").

1899. *N. lutea* Müller var. *scutellaris* Puton, Revue D'Entomologie, Tome xviii, p. 80 (credits var. name to "Sahlb. S.").

1904. *N. lutea* Müller var. *scutellaris* Kirkaldy, Wien. Ento. Zeit., xxiii, p. 132 (credits var. name to "Sahlb. S.").

1909. *N. lutea* Müller var. *scutellaris* Reuter; Oshanin, Verz. Palæ. Hem. I, p. 976.

1912. *N. lutea* Müller var. *scutellaris* Reuter; Oshanin, Catalog. der Paläarkt. Hem., p. 91.

1927. *N. lutea* Müller var. *scutellaris* Reuter; Esaki, Ann. & Mag. Nat. Hist. (9), xx, p. 286 (Footnote).

1928. *N. lutea* Müller var. *scutellaris* Reuter; Esaki, Ann. & Mag. Nat. Hist. (10), vol. II, p. 70.

1933. *N. lutea* Poisson, Annales de la Soc. Ento. de France, Janvier, 1933.

1933. *N. lutea* Poisson, Bull. de la Soc. Scien. de Bretagne, X, Fasc. III et IV (Reprint, p. 1).

Size. Length, 14-15 mm.;* width of pronotum, 4.8 mm.

Shape. Slightly more slender and less elevated on the back than *N. lutea* Müller.

Color. Typical color is luteous with a dark median spot on the anterior portion of scutellum and a brown band along costal area of hemelytra, which is broader in rear than in front.

Structural Characteristics. Anterior outline of head, viewed from above, flattened; vertex a little shorter than its anterior width; anterior margin of vertex less convex than the margin of an eye; anterior margin of vertex : synthlipsis : : 2 : 1. Pronotum usually less than twice as long as the head as seen from above; lateral margins of pronotum concave and only moderately divergent; anterior angles more sharply produced than in *N. lutea* Müller; lateral ledge as seen from the side nearly straight, but slightly oblique and a little longer than the rear margin of the eye below it. Scutellum subequal in length to pronotum. Ridge of hemelytral suture longer than scutellum. (Anterior lobe of membrane longer than posterior one.) Anterior trochanter of male with a hook; mesotrochanter

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* The specimens so kindly sent to me from France by Doctor Poisson are only slightly more than 12 mm. long and have the scutellum pale. See my comments under *N. lutea* Müller.

rounded. Middle femur with a stout anteapical tooth. Terminal abdominal sternite of female broad, more strongly constricted before the tip than in *N. lutea* Müller. First pair of gonapophyses in the female strong and moderately long. Male genital capsule with short digitate process and clasper as shown on Plate XVII, fig. 1.

Location of Type. Kirkaldy referred to *N. lutea* var. *scutellaris* J. Sahlb. and said it was exhibited to the Societas Fennica and a specimen given to him. I have this specimen before me. Doctor Kirkaldy was in error in assigning this species to J. Sahlberg, since Doctor Reuter had named it in 1886. The type ought, therefore, to be in Helsingfors, Finland. Since the name *N. scutellaris* was used by Fieber, 1851, for a Notonecta from South America, a change in name was necessary and, therefore, in 1928, *N. reuteri* was proposed.

Comparative Notes. This will be seen to be a species distinct from *N. lutea* Müller. Aside from a difference in the typical coloring, the shape of this species is more slender, the head and thorax are longer, and the male genitalia are different, as shown on Plate XVII, figures 1 and 2.

Data on Distribution. The J. Sahlberg specimen before me is from "Jaakima vii-20-1881." It is this specimen that is figured in Color Plate IV. Other specimens are recorded from Finland, Tammati; Jaakima, Finland (on the northwest shore of lake Ladoga and almost directly north of Petrograd). Doctor Kiritshenko has kindly given me specimens labeled "Lake Tsheznoje, near the rise of the river Oredezh, distr. Luga, Petrograd." Doctor Poisson writes me that the distribution of this species as he knows it is Finland, northern Russia and eastern Siberia.

There are in the British Museum three large, pale specimens, labeled by Kiritshenko *N. lutea* var. *scutellaris*, coming from "Amur" An examination of a male shows them to be smaller and paler than *N. amplifica,* but the male possesses a genital capsule and claspers like *N. amplifica* Kirit. 1930.

Notonecta viridis viridis Delcourt 1909

(Color Plate V, fig. 14; Plate XVII, fig. 12)

1909. *N. viridis* Delcourt, Bull, Sci. France de Belgique, xliii, p. 379; Tab. iv., lin. 2; Tab. v, lin. 18.

1924. *N. viridis* Poisson, Bull. Biol. Sci. France et Belique, lviii, Fasc. 1 (Life history and figures).

1925. *N. viridis* Poisson, Bull. Soc. Ento. France, 1925, p. 256. (Says *N. halophila* Edw. is a synonym.)

1928. *N. viridis* Hungerford, Annals Ento. Soc. Am., xxi, p. 143, pl. ix, fig. 1.

1928. *N. viridis* Esaki, Annals and Mag. Nat. Hist., ser. 10, vol. ii, pp. 68 and 74.

1933. *N. viridis viridis* Poisson, Annales de la Soc. Ento. de France. Janvier, 1933.

1933. *N. viridis viridis* Delcourt; Poisson, Bull. de la Soc. Scien. de Bretagne, Tom. X, Fasc. III et IV. (Reprint, p. 1.)

Referring to this species, also:

1848. ? *N.* var. *pallida* Amyot, Ento. Franc. Rhynch., p. 337 (nom invalid, note by Esaki).
1897. *N. glauca* var. *glauca* Kirk., Trans. Ento. Soc. London, 1897, p. 421 (in part).
1918. *N. halophila* Edwards, Ento. Mon. Mag., liv, p. 58.
1923. *N. halophila* Butler, Biol. Brit. Hem. Heter., p. 559.
1930. *N. halophila* Jones, *in* Reprint from The Entomologists Record, vols. XL-XLII, p. 69.

Size. Length, 14.4 mm. to 15 mm.; width of pronotum, 4.5 mm. to 4.8 mm.

Color. General facies light. Head and limbs of usual color, often suffused with green. Scutellum black. Hemelytra when fully pigmented as shown in Color Plate V. Usually the hemelytra are less pigmented, the dark pigment confined to a row of spots along costal area and an X-shaped figure, the center of which is just behind the tip of the clavus.

Structural Characteristics. Head not prominent. Anterior outline of head very slightly convex; vertex shorter than anterior width; margin of vertex less convex than margin of the eye; anterior breadth of vertex : synthlipsis :: 2 + : 1. Pronotum more than twice as long as the head; lateral margins only slightly divergent and plainly concave near the anterior end; anterior angles acutely produced and strongly embracing the eyes; lateral ledge distinctly sigmoid, nearly horizontal and a little longer than the rear margin of the eye below it; other characters like subspecies below.

Location of Type. In Delcourt's collection. I am very unhappy to differ with Doctor Esaki concerning this nomenclatorial problem. He gives some quite convincing arguments why this species should be called *N. marmorea viridis* Delc. and the next one *N. marmorea marmorea* Fabr.

At the time I labeled my colored plates I was inclined to accept Doctor Esaki's conclusions. After further reflection, however, I am forced to reject my former stand in the matter. Fabricius described *N. maculata* in 1794. This species he described from specimens taken near Paris and is a readily recognized species with "abdomen atrum, fascia baseos apiceque fulvis." Although he wrote "Scutellum album," it is generally conceded that this was a typographical error for "Scutellum atrum." The identity of this species is not disputed. Then, in 1803, he described specimens from Algeria as *N. marmorea* as follows: "*N. glauca* elytris testaceis fusco maculatis. Habitat in Algier. Dom. Stubb. Mus. Dom. de Sestestedt. Statura omnino *N. glaucae.* Caput et thorax glauca, immaculata. Scutellum atrum. Elytra testacea, fusco maculata. Corpus nigrum pedibus glaucis."

When he says "Corpus atrum pedibus glaucis" his attention may have been focused upon the underside of the entire body. To consider "Corpus atrum" as meaning the abdominal dorsum would not be true for *N. viridis* Delc. any more than for *N. maculata* Fabr., because Delcourt's species has the distal part of the abdomen pale above.

I agree that the remainder of the description seems to fit *N. viridis* Delc. However, there are no specimens of *N. viridis* coming down from Fabricius' time, and there are two specimens in the Museum at Copenhagen that are now labeled types and which were named by Fabricius. One is a male labeled "Mus. Seh. & T. Lund" and "*N. marmorea* ex. Algier Stub." The other is a female labeled "Mus. Seh. & T. Lund." The male now has the hemelytra open just enough to show the yellow base of the abdominal dorsum.

Delcourt, 1909 (p. 377), noted this, for he wrote "Les caractéres tout à fait particuliers de coloration jaune d'une partie des tergites et tout l'ensemble ne permettent pas d'en douter." He, too, had seen these types and declared them to be *N. maculata* Fabr. Esaki, 1928 (p. 72), writes: "Thus Delcourt synonymized *marmorea* with *maculata,* but he does not actually mention whether or not he examined the dorsal surface of the Fabrician specimens, and he was ignorant of the pronotal differences between *viridis* and *maculata.* I am of the opinion that the type specimens of authors writing at the time, when the conception of the type specimen was not yet established, cannot be accepted as the standard for the species, unless they well agree with the description of the author, because, in those days, so many specimens were not, or insufficiently, labeled that there were a great many possibilities of confusion. . ." I must report that in these two specimens the anterior lateral angles of the pronotum are not produced as in *N. viridis* Delc. The specimens are the same as *N. maculata* Fabr. I believe them to be the types of *N. marmorea* Fabr. and in spite of the description should be recognized as such. While Doctor Esaki's arguments would be acceptable if no historical specimens were at hand, it would be unwise to ignore the specimens in Copenhagen and apply the name to some other species which also fails to meet the requirements of the description in some particular.

Comparative Notes. Distinguished from other European species at once by the acutely produced anterior angles of pronotum which embrace the eyes (except *N. reuteri* Hungerford).

Data on Distribution. For the most part at least this form in-

habits brackish water, although Delcourt took it in fresh water near Paris and Poisson records it from Cæn and Rennes. Doctor Poisson writes me that the distribution as known includes England, the west and northwest coast of France and the fresh-water records in France as given above. My own specimens are from England.

Biological Notes. Doctor Delcourt in establishing this species based his conclusions regarding its specific distinctness more upon biological than structural evidence. He studied its natural habitat, its refusal to mate with *N. glauca* Linn., its less early development, its relative resistance to environmental adversity, and noted that its eggs and nymphs are smaller than those of *N. glauca* Linn. It remained for Edwards to point out a structural detail useful in determining this species. He pointed out the acute anterolateral angles of the pronotum of his *N. halophila,* which is now recognized to be *N. viridis* Delcourt. Like most other European species, this one deposits its eggs in the tissues of plants and winters as an adult insect.

Notonecta viridis mediterranea Hutchinson 1928

(Color Plate IV, fig. 5.)

1928. *N. viridis mediterranea* Hutchinson, Ento. Mo. Mag., lxiv, p. 35 (new name for *N. viridis meridionalis* Hutch.).

1933. *N. viridis mediterranea* Hutchinson; Poisson, Annales de la Soc. Ento. de France. Janvier, 1933.

1933. *N. viridis mediterranea* Hutchinson; Poisson, Bull. de la Soc. Scien. de Bretagne X. (reprint, p. 2).

Referring to this species, also:

1835. *N. glauca* var. *β* Burmeister, Handb. Ent. II, p. 190.

1840. ?. *N. marmorata* Spinola *fide* Fabr. Essai Ins. Hem., p. 59.

1840. *N. glauca* var. *maculata* Blanchard, Hist. Nat. Ins., iii, p. 89.

1843. *N. glauca* var. *marmorea* Amyot and Serville, Hem., p. 453.

1848. *N.* var. *marmorea* Amyot, Ento. Franc. Rhynch, p. 337 (Esaki says "nom. invalid").

1851. *N. fabricii* var. *marmorea* Fieber, Abh. Böhm. Gesel. Wis. (5), vii, p. 474.

1861. *N. fabricii* var. *marmorea* Fieber, Eur. Hem., p. 101.

1868. *N. glauca* var. *marmorea* Stal, Svensk. Vet. Akad, Handl., vii, No. 11 (Hem. Fabr.), p. 136.

1880. *N. glauca* var. *marmorea* Puton, Synop. Hém. Hétér. France, iii, p. 217.

1881. *N. glauca* var. *marmorea* Fabr., Puton, Synopsis, Hém. Hétér. France *in*: Memoires de la Société des Sciences de l'Agriculture et des Arts, 4° Série, Tom. ix, p. 121.

1888. *N. glauca* var. *marmorea* Reuter; Rev. Syn. Hétér. Palæarcticorum *in*: Acta Soc. Scient. Fennicæ, Tom. xv, p. 726.

1897, *N. glauca* var. *marmorea* Kirk., Rev. d'Ento., xvi, pp. 223, 224.

1897. *N. glauca* var. *marmorea* Kirk., Trans. Ento., Soc. London, 1897, p. 421.

1906. *N. glauca* var. *marmorea* Distant, Faun. Brit. Ind. Rhynch, iii, p. 42.

1907. *N. marmorea* Fabr.; Delcourt, Comptes Rendus des Séances et Mem. de la Soc. de Fr. Biologie, vol. 62, pp. 11-13.

1909. *N. viridis* Delcourt, Bull. Soc. France et Belgique, xliii, p. 379 (in part).

1909. *N. glauca* var. *marmorea* Oshanin, Verz. Palæ. Hem., I, p. 975.

1915. *N. glauca* var. *marmorea* Bollweg, Verh. des Naturhist. Vereins der Preussischen Rheinland und Westfalens 71, Jahrg. 1914, Mai, 1915, p. 174.

1922. *N. glauca* var. *marmorea* Despax, Bull. Soc. Hist. Nat. Toulouse, 1922, pp. 97-112.
1924. *N. marmorea* Poisson, Bull. Biol. de la France et de la Belg. T. lviii, Fasc. 1, p. 110.
1925. *N. viridis* Poisson, Bull, Soc. Ento. France, p. 328, fig. 1.
1927. *N. viridis meridionalis* Hutchinson, Ann. and Mag. Nat. Hist. (9), xx, p. 375 (description given, name later changed.).
1928. *N. marmorea marmorea* Esaki, Annals and Mag. Nat. Hist., ser. 10, vol. ii, p. 67.
1928. *N. viridis meridionalis* Poisson, Bull. Soc. Ento. France, No. 6, p. 107.
1929. *N. marmorea mormorea* Hutchinson, Annals of South African Mus., vol. xxv, pt. 3, p. 363.

Size. Length, 13.2 mm. to 14.4 mm.; width of pronotum, 4.2 mm. to 5 mm.

Color. Some specimens are colored as in the illustration on Color Plate IV, others show the rear half of pronotum dark, due to the black mesonotum beneath, and have the lighter markings of the hemelytra tan to pale orange. Scutellum black. The costal area of the hemelytra nearly always checkered with a row of roughly rectangular spots. Venter black except connexivum and tip of abdomen.

Structural Characteristics. Head not prominent. Anterior outline of head moderately convex; vertex shorter than anterior width; margin of vertex less convex than margin of the eye; margin of vertex longer than frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 2 + : 1. Pronotum more than twice as long as the head; lateral margins only moderately divergent and slightly concave; anterior angles acutely produced and embracing the eyes; lateral ledge, as seen from the side, distinctly sigmoid, nearly horizontal and a little longer than rear margin of the eye below it. Scutellum longer than the pronotum. Anterior lobe of membrane longer than the posterior. Anterior trochanter of male with slight obscure elevation. Mesotrochanter rounded. Terminal abdominal sternite of female large, constricted near the tip, which is bluntly pointed. First pair of gonapophyses moderately long.

Location of Type. Now in British Museum. Type labeled "Astroni near Naples, Italy, 19, IV, 1926."

Data on Distribution. I consider the species to include 3 subspecies, one of which is *N. viridis mediterranea* Hutch., and have seen specimens labeled as follows: "Egypte, Bir-Hooker, J. Dewitz, 1904;" "Milano, Italy; Tyrolia, J. Sahlb;" "Bethlehem, J. Sahlb;" "Kotschy, Ost Medit." (Vienna Mus.); "Baluchistan, Kushdil, Khan Pishin, India"; "Plateau Persan occid. De Hamadan a Zendjan J. de Morgan, 1904 (Paris Mus.)." Doctor Poisson has kindly supplied me with the following distributional notes: "Southern France, Spain, North Africa, Italy, Sardinia, Sicily, Corsica, Hungary, Greece, Cyprus, Macedonia, Asia-minor, Palestine, Cri-

mea, Transcaspia, Persia, Turkestan. About the Mediterranian, but showing a tendency toward a vast dispersion east and southeastward." My own observations extend this eastward distribution to India, and Hutchinson lists Daulatabad, Seistan.

Notonecta viridis kashmiriana new subsp.

(Color Plate V, fig. 13; Plate XVII, fig. 5)

Size. A little smaller than the others.

Color. Typical color as shown on Color Plate V.

Structural Characteristics. Closely related to *N. viridis mediterranea* Hutch. The synthlipsis relatively a trifle wider, the lateral margins of the prothorax more divergent and the genital claspers of the male as figured on Plate XVII, fig. 5.

Location of Types. Holotype and allotype in Indian Museum, Calcutta; paratypes in Francis Huntington Snow Entomological Museum, University of Kansas. Described from five specimens labeled: "Kashmir Survey, Pond on roadside near Missionary Hospital, Sprinagar, Kashmir, N. W. Himalayas, Sta. 3, 10, VI, 21."

Discussion. There is before me also a series labeled: "Daulatabad, Seistan 20. XII, 18. Sta. 29, B. S. Village Pond." In these the male genital clasper is not quite like the above, but intermediate between it and *N. viridis mediterranea* Hutch. These groups appear to involve the same problem encountered with *N. unifasciata* Guérin in America.

NOTONECTA OF WESTERN HEMISPHERE

KEY TO NOTONECTA OF NORTH, CENTRAL, AND INSULAR AMERICA†

1. Keel of fourth abdominal sternite bare, the hairs confined to the sides. (See Plate X, figs. 1 and 2) .... (2)
   Keel of fourth sternite not bare (except in *N. borealis*). (See Plate X, figs. 3 and 4, (14)
2. Head broad; eyes large and broad, rear width usually greater than length of the lateral margin of pronotum; scutellum conspicuously broader than long; last abdominal sternite of female narrow, side margins usually concave. (See Plate X, fig. 1) .... (3)
   Head not conspicuously broad and short. Eyes not transverse, rear width not as great as length of lateral margin of pronotum. Scutellum not conspicuously broader than long. The last abdominal sternite of female not narrow with concave side margins. (See Plate X, figs. 2 and 3) .... (12)
3. Lateral margins of pronotum of males straight* and nearly so in female. Penultimate abdominal sternite of female slender at tip .... (4)
   Lateral margins of pronotum of males at least slightly concave, females plainly so. Penultimate abdominal sternite of female fairly broad, explanate near caudal end or, if slender, plainly running to this section by the concave lateral margins of pronotum .... (6)

† Read Section III beginning p. 12.

* Males of *N. ceres stirtoni* have lateral margins of pronotum almost straight, but the females have the margins plainly concave.

4. Length not more than 12 mm. Last abdominal sternite of male not unusually broad. Penultimate abdominal sternite, of female, pointed at tip. Last sternite slender. (See text figure 3)....................................*N. hoffmanni.*
(California, Arizona and Lower California, p. 68.)

Length more than 12 mm. Last abdominal sternite of male unusually broad. Penultimate abdominal sternite of female not pointed, but more or less incised at tip and last sternite rather broad. (Plate X, fig. 1)...................... (5)

5. Genital capsule of male with large lobe in front of clasper. Penultimate abdominal sternite of female plainly notched at tip............................*N. lobata.*
(New Mexico, Texas, Mexico, p. 70.)

Genital capsule without large lobe in front of clasper. Penultimate abdominal sternite of female faintly notched at tip...........................*N. hintoni.*
(Mexico, p. 72.)

6. Anterolateral angles of pronotum acute and snugly embracing the eyes. (Plate XVII, fig. 4).. (7)

Anterolateral angles of pronotum not as above (See Plate VIII, fig. 8)............ (9)

7. Lateral margins of pronotum abruptly constricted, greatly so in female. Last abdominal sternite of female broad. (Text figure 5)............*N. compacta.*
(Mexico, p. 73.)

Lateral margins of pronotum concave, not abruptly constricted. Last abdominal sternite of female narrow. (Text figure 5)................................ (8)

8. Length more than 12 mm..*N. mexicana.*
(Mexico, p. 75.)

Length 12 mm. or less..*N. m. creaseri.*
(Mexico, p. 77.)

9. Large and robust. Male clasper without sharp basal projection. Females with lateral margins of pronotum constricted just behind the anterolateral angles, which flare outward..*N. robusta.*
(Mexico, p. 78.)

Size moderate to small for this subgenus. Male clasper with a sharp basal projection. Females not as above.. (10)

10. Lateral margins of pronotum of male almost straight. Penultimate abdominal sternite of female fairly broad and expanded before the tip. (Text figure 6)
N. ceres stirtoni.
(Mexico, p. 80.)

Lateral margins of pronotum of male plainly concave. Penultimate abdominal sternite of female narrow and slightly expanded before the tip. (Text figure 6). (11)

11. Length 12 mm. or less. The lateral margins of the pronotum of female constricted near the middle...*N. ceres ceres.*
(Costa Rica, p. 79.)

Length more than 12 mm. The lateral margins of the pronotum of female constricted in front of the middle.................................*N. c. rogersi.*
(Costa Rica, p. 81.)

12. Keel of fourth and fifth abdominal sternites bare, the hairs confined to the sides ....*N. impressa and N. montezuma.*
(Mexico and Texas, pp. 81 and 82.)

Keel of fourth abdominal sternite only bare, the hairs confined to its sides......... (13)

13. Synthlipsis usually less than one-half width of eye. Metaxyphus typically yellow. Head one-half as long as pronotum............................*N. insulata.*
(Eastern Canada and Northern United States east of 100th meridian, p. 84.)

Synthlipsis usually fully one-half to two-thirds width of eye. Metaxyphus typically black. Head less than one-half as long as pronotum................*N. kirbyi.*
(Western Canada, Northern United States, west of 100th meridian and south to Texas, p. 88.)

14. Last abdominal sternite of female large but strongly constricted just before the tip. Male with digitate prolongation on genital capsule........................... (15)

Last abdominal sternite of female not large nor strongly constricted just before the tip. Male without digitate prolongation on the genital capsule................. (16)

15. Color dark, scutellum black, hemelytra irrorated with brown and blue-black. Synthlipsis narrow, only one-third anterior margin of vertex viewed from above. ....*N. irrorata.*

(Eastern Canada and Eastern United States south to Gulf and west to Kansas, p. 92.)

Color light, scutellum pale, hemelytra pale.* Synthlipsis greater than one-third anterior margin of vertex..*N. borealis.*

(Across Canada and in Michigan and Minnesota, U. S. A., p. 95.)

16. Pronotum broad in front, embracing the eyes, which are flattened and receding from the anterior margin of the vertex. Synthlipsis broad, one-half anterior margin of vertex as seen from above. Scutellum plainly broader than long. Males with stout tubercle at angle of front trochanter and a very stout, broad hook as shown on Plate IX, fig. 4.. (17)

Pronotum not broad in front. Eyes not as above. Scutellum not plainly transverse. Males without stout tubercle at angle of front trochanter and with a small hook on its anterior surface.. (21)

17. Length usually not more than 12 mm.. (18)

Length usually more than 12 mm... (19)

18. Pronotum steeply declivant as viewed from the side. Dark form with hemelytra brown to nearly black without luteous stripes. Luteous form with tinge of orange. Male genital capsule as on Plate XIII...................*N. melaena.*

(Mexico, p. 97.)

Pronotum not steeply declivant. Dark form unknown to me. Luteous form pale luteous. Male genital capsule with a thickened protuberance on keel...

N. ochrothoe.

(Southern California to Colombia, S. A., p. 99.)

19. Anterior end of lateral ledge of pronotum broadly flattened, the ledge plainly wider beneath than the diameter of the second antennal segment. Penultimate abdominal sternite of female broadly triangular. (Text figure 7).....*N. repanda.*

(Arizona to Mexico, p. 100.)

Anterior end of lateral ledge of pronotum not broadly flattened, scarcely, if any, wider than the diameter of the second antennal segment. Penultimate abdominal sternite of female slenderly triangular. (Text figure 7)..................... (20)

20. Caudal half of lateral margin of pronotum plainly undulate as seen from side. Vertex of female not as below. Male genital capsule as on Plate XIII, fig. 8.

N. shooteri.

(California, p. 101.)

Caudal half of lateral margin of pronotum of male nearly straight. Anterior margin of vertex of female considerably produced beyond the very receding eyes. . . ..*N. colombiana.*

(Colombia, S. A., p. 128.)

21. Mesotrochanter plainly angulate or produced into a tooth or stout spinelike process, (22)

Mesotrochanter rounded or nearly so... (26)

22. Synthlipsis very narrow, not more than one-sixth the anterior margin of the vertex as seen from above. Hemelytra brick red to orange with black blotch on corium ....*N. uhleri.*

(Eastern United States from Massachusetts to Florida westward to Mississippi river, p. 103.)

Synthlipsis usually broader than above. Hemelytra not red or orange............. (23)

23. Scutellum typically pale.. (24)

Scutellum typically black with flavous lateral margins.......................... (25)

24. Synthlipsis about one-fourth width of eye..........................*N. raleighi.*

(Southeastern United States, p. 105.)

Synthlipsis about one-third width of eye............................*N. lunata.*

(Eastern Canada and northern states west to Wisconsin, p. 107.)

25. Synthlipsis at least one-half anterior margin of vertex. Mesotrochanter not produced into a long spinose process................*N. unifasciata* and subspecies.

(Mexico north to western Canada, pp. 109 to 111.)

Synthlipsis less than one-half anterior margin of vertex. Mesotrochanter produced into a long spinose process.................................*N. spinosa.*

(Western Canada and northwestern U. S. A., p. 112.)

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*Often there is a dark submarginal streak, and rarely the scutellum is black and the hemelytra marked nearly as in *N. irrorata* Uhler.

26. Synthlipsis distinctly less than one-half anterior margin of vertex, head prominent, hemelytra usually black and white .... (27)
Synthlipsis nearly one-half anterior margin of vertex. Head not prominent. Pale or marked with black .... (28)
27. Anterior margin of vertex (seen from above) straight and width less than length of vertex. Male clasper broad, shallowly incised at tip. Last abdominal sternite of female with apical notch broader than deep if present. Typical color with broad black band across distal end of hemelytra .... *N. indica*.
(North America south of 37° latitude, Insular America, S. A., p. 113.)
Anterior margin of vertex rounded and width subequal to length of vertex. Male clasper deeply incised. Last abdominal sternite of female with apical notch deeper than broad. Typical color with narrow undulate band across hemelytra .... *N. undulata*.
(Across Canada, widespread in United States to Mexico, p. 117.)
28. Male clasper bifurcate .... (29)
Male clasper not bifurcate. (Plate XIV, fig. 8) .... *N. indicoidea*.
(Mexico, p. 123.)
29. Clasper broad and deeply furcate. (Plate XIII, fig. 7) .... *N. confusa*.
(South America, p. 130.)
Clasper plump and shallowly notched. (Plate XIII, fig. 9) .... *N. distinctoidea*.
(Mexico, p. 124.)

*Notonecta hoffmanni** Hungerford 1925

(Color Plate III, fig. 12; Plate XI, fig. 6; text figure 3.)

1925. *N. hoffmani* Hungerford, Can. Ento. lvii, p. 241, pl. vi, fig. 6.

Referring to this species also:

1894. *N. mexicana* Uhler, Proc. Calif. Acad. Sci. (2), iv, p. 292.
1897. *N. mexicana* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 402. (Bassee Californie, Diguet 1895, Paris Mus.)
1901. *N. mexicana* Champion, Biol. Centr. Amer. Hem.-Het. ii, p. 368.
1905. *N. mexicana* Bueno, Jl. N. Y. Ento. Soc. xiii, p. 158 (in part).
1907. *N. mexicana* Kirkaldy and Bueno, Proc. Ento. Soc. Wash. x, p. 198 (in part).
1914. *N. mexicana* Van Duzee, Trans. San Diego Soc. Nat. Hist. ii, p. 33.
1917. *N. mexicana* Van Duzee, Catalog of Hem. p. 454 (in part).
1919. *N. mexicana* Hungerford, Kans. Univ. Sci. Bull. xi, p. 170 (in part).

Size. Length, 10 mm. to 11.5 mm.; width of pronotum, 3.9 mm. to 4.5 mm.

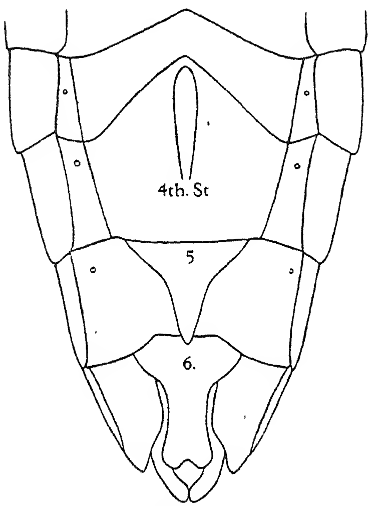
Color. Orange red and black to horn and black. Head, pronotum and limbs yellow. Scutellum black. Membrane of hemelytra from dusky to brownish black. Trochanter and femur of middle and hind legs with the longitudinal dark stripe characteristic of the *N. mexicana* A. & S. group.

Structural Characteristics. Head large, anterior outline, as viewed from above, flattened; vertex a little longer than its anterior width; anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 3:1, sometimes a little broader. Pronotum about one and eight-tenths the length of the head; lateral margins moderately divergent and nearly straight, somewhat explanate on anterior two-thirds,

* Name in honor of W. E. Hoffmann and one "n" omitted in error.

anterior lateral angles rounded; lateral ledge, as seen from the side, nearly straight. Anterior lobe of membrane of hemelytron larger and longer than the posterior one. Anterior trochanter of the male with a short, inconspicuous hook. Mesotrochanters rounded. Carina of fourth abdominal sternite bare; last abdominal sternite of female slender, boarder at tip than middle and incised at tip. First pair of gonapophyses short. Male genital capsule as shown on Plate XI.

Location of Types. In the Francis Huntington Snow Entomological Museum of the University of Kansas. Described from a series of insects taken at Laguna Beach,* California, C. T. Dodds, collector. Other paratypes from California and Lower California.



N. hoffmanni.

TEXT FIGURE 3. *N. hoffmanni* Hungerford, showing the venter of the abdomen of a female. Compare with text figures 5 and 6. (Subgenus Erythronecta.)

Comparative Notes. This species belongs to the *N. mexicana* A. & S. group and until 1925 was confused with *N. mexicana* A. & S. It is a trifle smaller than *N. ceres* Kirkaldy, from which it differs in having almost straight, not sinuate, lateral margins of the prothorax.

Data on Distribution:

CALIFORNIA. Laguna Beach, C. T. Dodds; Laguna Mts., July 6, 1929, L. D. Anderson; Alpine, July 9, 1929, R. H. Beamer; San Diego Co., July 4, 1929, L. D. Anderson; San Diego Co., August 5, 1913, E. P. Van Duzeé (Drake Coll.); San Diego Co., April 9, 1930, C. & D. Martin; Indio, July 24, 1929, L. D. Anderson; Claremont, C. F. Baker (Uhler Coll.); Monrovia Canyon, March 2, 1930, Mrs. C. H. Martin; Mission Creek, Santa Barbara, 1915, C. H. Kennedy; California, L. Lethierry (Det. by him as *N. mexicana*); Winters, August 6, 1929, R. H. Beamer.

* Not Long Beach, as stated in original description.

ARIZONA. Huachuca Mts., 5,200 ft., May 20, 1919, R. D. Champ.; Salome Creek, Sierra Ancha Mts., Gila Co., September 1, 1932, D. K. Duncan; Chiricahua Mts., Pinerey Canyon, Hands Ranch, June 16, 1932, D. K. Duncan.

LOWER CALIFORNIA, MEXICO. El Paraiso, May, 1889, Chas. D. Haines. (Det. by Kirkaldy as *N. mexicana*). Santa Maria, May, 1889, Chas. D. Haines (Uhler Coll.).

Notonecta lobata Hungerford 1925

(Color Plate III, figs. 5, 10, 11, 13; Plates X, fig. 1, and XI, fig. 2.)

1925. *N. lobata* Hungerford, Can. Ento. lvii, p. 239, Pl. vi, fig. 3.
1928. *N. lobata* Hungerford, Annals Ento. Soc. Amer. xxi, p. 142.
1931. *N. lobata* Bueno, Bull. Brooklyn Ento. Soc. xxvi, No. 3, p. 138.

Referring to this species, also:

1884. *N. mexicana* Uhler, Standard Nat. Hist. II, p. 252.
1897. *N. mexicana* Kirkaldy, Trans. Ento. Soc. London for 1897, pp. 401, 402 (in part).
1901. *N. mexicana* Champion, Biol. Centr. Amer. Hem.-Het. II, p. 368 (in part).
1905. *N. mexicana* Bueno, Jl. N. Y. Ento. Soc. xiii, p. 158 (in part).
1906. *N. mexicana* Snow, Trans. Kans. Acad. Sci. xx, pt. 1, p. 181.
1907. *N. mexicana* Snow, Trans. Kans. Acad. Sci. xx, pt. 2, p. 160.
1909. *N. mexicana* Kirkaldy and Bueno, Proc. Ento. Soc. Wash. x, p. 198.
1918. *N. mexicana* Hungerford, Ento. News xxix, p. 245, pt. xv, fig. 7.
1919. *N. mexicana* Hungerford, Kans. Univ. Sci. Bull. xi, p. 170 (in part).
1919. *N. mexicana* Hungerford, Kans. Univ. Sci. Bull. xi, pl. xxxii, fig. 4 (male genital capsule).

Size. Length, 13 mm. to 14 mm.; width of pronotum, 4.3 mm. to 5 mm.

Color. Typically red and black. Some specimens are brownish black with beige trimmings and others are greenish-tan. All have the head, pronotum and limbs yellow or gray and scutellum and membrane of hemelytron black. The hemelytra, excepting the membrane, are typically red. The males of the red forms frequently have the black of the membrane extending forward upon the distal portion of clavus and corium. The pale and dark forms have only the slightest suggestion of red. Middle and hind trochanters and femora with longitudinal median streaks of brown or black.

Structural Characteristics. Head large, anterior outline, as viewed from above, flattened; vertex slightly longer than its anterior width; anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 19:7. Pronotum about one and two-thirds length of the head, lateral margins divergent, straight in male and nearly so in female. Anterior angles normal; lateral ledge as seen from the side sinuate and oblique and shorter than the rear margin of eye below it; anterior half moderately explanate. Anterior lobe of membrane larger than the posterior one. Anterior trochanter of the male with short inconspicuous hook. Mesotrochanters rounded. The keel of fourth abdominal sternite bare. Last abdominal sternite of female slender,

not, or little, broader at tip than middle, tip incised. First pair of gonapophyses short. Last abdominal sternite of male unusually broad and rounded; male genital capsule with large lobe in front of clasper. (See Plate XI, fig. 2.)

Location of Types. In the Francis Huntington Snow Entomological Museum of the University of Kansas; seventeen specimens taken by P. A. Glick in the Superstition Mountains, Arizona.

Comparative Notes. This species belongs to the *N. mexicana* A. & S. group and, until 1925, was confused with *N. mexicana* A. & S. It is a common species in the southwest part of the United States.

Data on Distribution:

ARIZONA. Superstition Mts., November 11, 1922, P. A. Glick; Santa Rita Mts., Alt. 8,000 ft., June 19, F. H. Snow; Santa Rita Mts., July 25, 1927, and July 17, 1932, R. H. Beamer; Sabino Canyon, July 14, 1932, R. H. Beamer; Grand Canyon, 6 miles below North Haxasn Crk., September 16, 1923, R. C. Moore; Huachuca Mts., 5,750 ft., March 16, 1919, R. D. Camp (Univ. of Mich.); Baboquivari Mts., July 18, 1932, R. H. Beamer; Huachuca Mts., July 8, 1932, R. H. Beamer; Cochise Co., July 29, 1927, L. D. Anderson; Pima Co., July 27, 1927, R. H. Beamer; Gila Co., August 5, 1927, P. A. Readio; Yuvapai Co., August 9, 1927, L. D. Anderson; Chiricahua Mts., Pinerey Canyon, Hands Ranch, 5,000 ft., June 16, 1932, D. K. Duncan; S. Catalina Mts., Sabina Canyon, 3,000 ft., June 20, 1932, D. K. Duncan; Reservation Springs, 12 miles N. E. of Globe, September 17, 1932, D. K. Duncan. The following in U. S. N. M.: Ariz. (Uhler Coll.); Sabina Canyon, Hubbard Hot Springs, June 26, H. S. Barber; Bright Angel, Colo. Canyon 3,500 ft., H. S. Barber; Senator Mine, near Prescott, September 12, 1907, H. S. Barber; Catal, Spr. April 19, H. G. Barber; Huachuca Mts.; Santa Rita Mts., July 26, 1925.

NEW MEXICO. San Antonio, July 15, 1927, L. D. Anderson.

TEXAS. Valentine, July 13, 1927, L. D. Anderson; Presidio Co., July 15, R. H. Beamer. The following in U.S.N.M.: Kerrville, April 12, 1907, F. C. Pratt; Brewster Co., Chisos Mts., June 10-12, 1908, Mitchell and Cushman; Fort Davis, Jeff Davis Co., 5,000 ft., Davis Mts., Mrs. O. C. Poling (H. M. Harris).

MEXICO. Mex. (Uhler Coll.).

Biological Notes. On May 12, 1932, Mr. Douglas K. Duncan visited a small pool which is located twelve miles northeast from Globe, Arizona, on the Showlow road and two miles due east from the highway down a canyon. There is a small spring forming a small pool about six feet by six feet and from a few inches to eighteen inches deep; sandy and rock bottom; some moss, submerged twigs, etc. The elevation is about 4,000 feet. In this pool he took all the adults he could find, five of them, and noted many nymphs. On May 16th he again visited the pool and could find no adults, but took more than fifty nymphs for me, leaving about twenty others to mature. There were no other species of Notonecta in the pool.

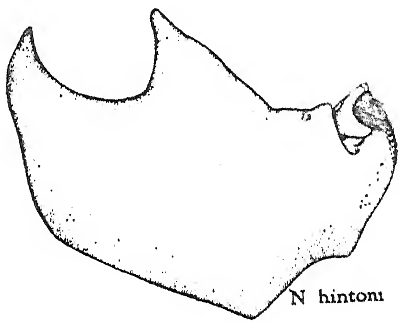
Notonecta hintoni new species

(Text figure 4)

1934. *N. hintoni* Hungerford, Jl. Kans. Ento. Soc. VII, No. 3, p. 97.

Size. Length, 14 mm. to 15 mm.; width of pronotum, 5.1 mm.

Color. Typically red and black. Some specimens may have the red replaced by tan. All have the head, pronotum and limbs yellow or gray and scutellum and membrane of hemelytron black. The hemelytra of females are typically red, excepting the membrane and a spot near the distal angle of the corium, which are black. The males are darker, having the red of the corium and clavus more or less suffused with black. Middle and hind trochanters and femora with longitudinal median streaks of brown or black.



TEXT FIGURE 4. *Notonecta hintoni* Hungerford, showing male genital capsule. Compare with drawings on Plate XI.

Structural Characteristics. Head large, anterior outline, as viewed from above, flattened; vertex of male slightly longer than its anterior width, subequal in female; anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 19:7. Pronotum not more than one and two-thirds length of head; lateral margins divergent, straight to faintly concave; anterior angles about normal, slightly more produced than in *N. lobata* Hungerford; lateral ledge, as seen from the side sinuate and oblique and shorter than rear margin of eye below it; anterior half moderately explanate. Anterior lobe of membrane larger than the posterior one. Anterior trochanter of the male with an inconspicuous hook. Mesotrochanter rounded. The keel of the fourth abdominal sternite bare. Last abdominal sternite of female slender, sides not concave, tip incised. Last abdominal sternite of male unusually broad and rounded; male

genital capsule as shown in figure 4. The clasper strikingly different from any other member of the subgenus Erythronecta.

Location of Types. Holotype, allotype and paratypes in the Francis Huntington Snow Entomological Museum. Paratypes will be sent to United States National Museum and to British Museum. Described from a series of twenty-nine specimens taken by Mr. H. E. Hinton in Real de Arriba, District of Temascaltepec. Altitude, 1,960 meters, Mexico.

Comparative Notes. General appearance that of *N. lobata* Hungerford. The males are distinguished from that species by the very different shape of the genital capsules and claspers. The females by having only an inconspicuous notch at tip of penultimate abdominal sternite. Lateral margins of last abdominal sternite of female not as curved as in *N. lobata* Hungerford.

Data on Distribution. Known only from the type locality.

Notonecta compacta Hungerford 1925

(Color Plate III, fig. 6; Plate XI, figs. 3 and 8; and text fig. 5)

1925. *N. compacta* Hungerford, Can. Ento., lvii, p. 239.
1933. *N. compacta* Hungerford, Bull. Brook. Ento. Soc., xxviii, p. 135 (allotype ♂).

Referring to this species, also:

1897. *N. mexicana* Kirkaldy, Trans. Ento. Soc. London (in part).
1901. *N. mexicana* Champion, Biol. Centr. Amer. Hem. Het. II, p. 369 (Amula in Guerrero).

A dark male from Amula studied by Champion and another by Kirkaldy, labeled *N. mexicana* A. and S. by them. There is another specimen in Oxford Museum labeled by Kirkaldy.

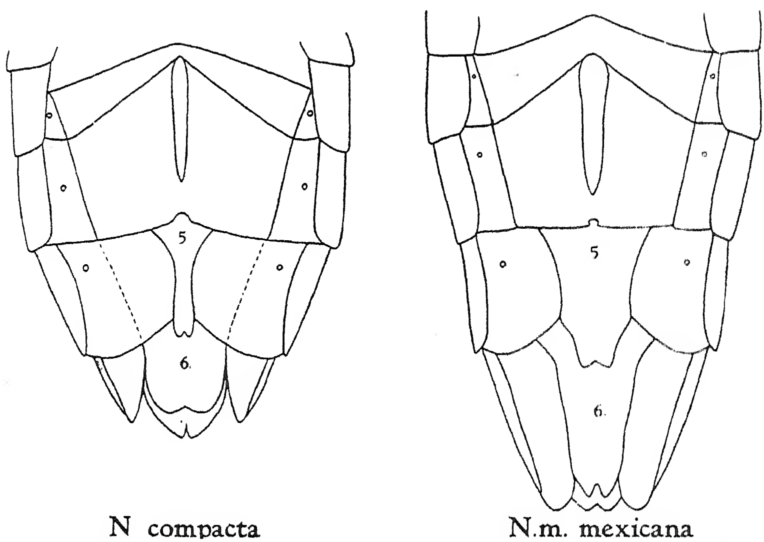
Size. Length, 12.5 mm. to 14 mm.; width of pronotum, 4.8 mm. to 5.7 mm.

Shape. A comparatively short, plump-bodied species. The lateral margins of the prothorax in the female strongly constricted in the middle.

Color. Females are usually red and black and males nearly black. I have some females that are black like the males. Head, pronotum and limbs dark testaceous. Femora with dark longitudinal stripes beneath and the trochanters each with a dark elongate spot.

Structural Characteristics. Head large; anterior outline of head viewed from above, flattened; vertex slightly longer than its anterior width in the male, subequal in the female; anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 3 + :1. Pronotum about twice the length of the head in female. Head of male longer than half

of the pronotum; lateral margins divergent, moderately constricted in the male but very strongly and characteristically constricted in the female. Anterior angles embracing the eyes. Lateral ledge unlike in the two sexes, sigmoid and oblique in both sexes as seen from the side; in the female the ledge is heavy and pronounced on the anterior half and almost obliterated and curved on the posterior half; in the male the anterior portion of the ledge is broader than elsewhere but not interrupted; anterior end of the ledge deflected in both sexes, margin of prothorax shorter than the rear margin of the eye below it. Scutellum a little longer than the pronotum. Posterior and anterior lobes of membrane subequal, the posterior sometimes a trifle longer. Anterior trochanters of the male with broad, blunt hook. Mesotrochanters not angulate. The carina or keel of the fourth abdominal sternite bare; this segment is short in the male and long in the female. In the male the penultimate abdominal sternite is enlarged. The terminal abdominal sternite of the female is as broad as long (exposed part) with lateral edges concave and tip incised. First pair of gonapophyses short. Male genital capsule as shown on Plate XI.



TEXT FIGURE 5. *Notonecta compacta* Hungerford and *Notonecta m. mexicana* A. & S. Underside of abdomen of females. (Subgenus Erythronecta.)

Location of Type. The type is in the U. S. N. M.

Comparative Notes. This species belongs to the *N. mexicana* A. and S. group. The last abdominal sternite of the female is more

nearly quadrate than in the other species. No other species has the pronotum so conspicuously constricted laterally.

Data on Distribution. Colima, Mexico, coll. by L. Conradt; Amula, Guerrero, 6,000 ft., H. H. Smith; Between Cajones and Rincon, S. of Chilpancingo, Guerrero, Mex., July 1, 1932, Hobart Smith (18 specimens); Near Taxco, Guerrero, Mex., July 4, 1932, Hobart Smith (2 specimens). A male of the Hobart Smith collection is the allotype.

Notonecta mexicana mexicana Amyot and Serville, 1843

(Color Plate III, fig. 8; Plate XI, fig. 11; text figure 5.)

1843. *N. mexicana* Amyot & Serville, Hémiptères p. 453, Pl. viii, fig. 7.

1851. *N. mexicana* Amyot & Serville; Fieber, Rhynchotographieen, p. 475.

1851. *N. mexicana* Amyot & Serville; Fieber, Rhynchotographien, p. 51. (Van Duzee.)

1853. *N. mexicana* Herrich-Schaeffer, Wanzen. Ins. ix, p. 43, Tab. ccxciv, fig. 903 (in color).

1884. *N. mexicana* Uhler, Standard Nat. Hist., ii, p. 252 (in part).

1897. *N. mexicana* Amyot & Serville; Kirkaldy, Trans. Ento. Soc. London for 1897. p. 401 (in part).

1901. *N. mexicana* Amyot & Serville; Champion, Biol. Centr. Amer. Hem.-Het. ii, p. 368-369 (in part, but not figures). (Mexico, Sallé; Oaxaca, Sallé; San Luis Potosi, Palmer.)

1904. *N. mexicana* Amyot & Serville; Kirkaldy, Wien Ento. Zeit., xxiii, pp. 94 and 132 (in part).

1905. *N. mexicana* Amyot & Serville; Bueno, Jl. N. Y. Ento. Soc. xiii, pp. 145, 150, 158. (Ref. not localities.)

1909. *N. mexicana* Amyot & Serville; Kirkaldy & Bueno, Proc. Ento. Soc. Wash., x, p. 198 (in part).

1917. *N. mexicana* Amyot & Serville; Van Duzee, Catalogue Hemip., p. 454 (in part).

1919. *N. mexicana* Amyot & Serville; Hungerford, Kans. Univ. Sci. Bull. xi, (in part).

1925. *N. mexicana* Amyot & Serville; Hungerford, Can. Ento. lvii, p. 238.

1928. *N. mexicana* Amyot & Serville; Hungerford, Jl. Kans. Ento. Soc. v, p. 53.

Referring to this species, also:

1851. *N. klugii* Fieber, Rhynchotographieen p. 475 (in part).

1851. *N. klugii* Fieber, Rhynchotographien p. 51 (Van Duzee).

1925. *N. macrocephala* Hungerford, Can. Ento. lvii, p. 241, Pl. 6, fig. 5. (Syn. new.)

Size. Length, 13 mm. to 14 mm.; width of pronotum, 4.6 mm. to 5.1 mm.

Color. Typically a red and black species. The males a little darker than the females as a rule. Probably there exist black and tan females and black males, but I have never seen them. Anterior half of prothorax, head and limbs yellow, the middle and hind trochanters and femora with a median longitudinal dark stripe, front femur may have two such stripes on its rear margins, posterior half of pronotum may be darkened by the black mesonotum beneath. Scutellum black.* Clavus and corium orange red to red. Smoky or black areas may occur along hemelytral suture, beneath corial-

*Footnote: I have seen a specimen or two with yellowish scutellum that were otherwise fairly well colored.

claval suture, on the embolium, on outer half of corium and on membrane, which is nearly always dark.

Structural Characteristics. Head large, embraced at base by the anterior angles of prothorax. Anterior outline of the head, viewed from above, flattened; vertex subequal in length to its anterior width, sometimes in the male a little longer, anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 17:7. Pronotum not quite twice the length of the head, lateral margins moderately divergent, somewhat concave in the male, more so in the female. Anterior angles acute and embracing the eyes, more pronounced in the male than in the female. Lateral ledge moderately broad and horizontal on anterior half and oblique and nearly obliterated on posterior half; anterior angle slightly deflected in both sexes; margin of prothorax shorter than the rear margin of the eye beneath. Anterior lobe of membrane of hemelytra a little longer than the posterior. Anterior trochanters of male with a hook of moderate size, mesotrochanters rounded, the carina of the fourth abdominal sternite bare, the terminal abdominal sternite of female slender, elongate, but slightly constricted and the tip incised. First pair of gonapophyses rather slender. Male genital capsule as shown on Plate XI.

Location of Type. I have been unable to find the types in Paris or elsewhere.

Comparative Notes. The description I have given above applies to the species that fits best Amyot and Serville's brief description and the color drawing. The size (14 mm.), the parallel sides and the distribution point to this species. In former writings I have been confused by Kirkaldy and Champion and believed *N. mexicana* A. & S. to be something else. I now conclude that my *N. macrocephala* is only an unusual specimen of this species and, therefore, suppress it. I described it from a single specimen with an abnormally large head, but the genitalia are indistinguishable from the species described above. The slender, tapering last abdominal sternite of the female distinguishes this species.

Data on Distribution. Described from "Mexico," and unfortunately most of the specimens I have seen bear no more precise label. However, in the Museum at Vienna there is a specimen labeled "San Luis Potosi, Dr. Palmer." This was determined by Champion as *N. mexicana*. There is another specimen from Signoret's collection labeled "Bogota." There are two specimens from Mexico by Sallé in the museum at Stockholm.

Notonecta mexicana v. *creaseri* Hungerford 1932

(Color Plate II, fig. 13; Plate XI, figs. 1 and 9.)

1932. *N. mexicana* v. *creaseri*, Hungerford, Jl. Kans. Ent. Soc., v., p. 53.

Size. Length, 12 mm.; width of pronotum, 4.3 mm.

Color. The four specimens at hand are tan and black with one specimen showing some flecks of red on the corium. Head and legs testaceous. The femur with a longitudinal stripe which is characteristic of entire group. Scutellum is black or nearly so, three of the specimens with lateral margins tan. The clavus and corium mostly tan. The distal third of corium more or less dark. Membrane nearly black. It is probable that this variety, like other species in the group, may have red or nearly black in place of the tan on the hemelytra.

Structural Characteristics. Anterior outline of the head, viewed from above, flattened; vertex longer than its anterior width; margin of vertex less convex and shorter than frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 11:4 (in the female). In the male the synthlipsis is a little narrower. Pronotum about twice length of head; lateral margins short, divergent, but quite concave in the females and plainly so in the males; anterior angles embracing the eyes; lateral ledge as seen from the side with anterior three-fifths broad and nearly horizontal and posterior two-fifths faint and oblique; the anterior angle deflexed; the length of the ledge less than the rear margin of the eye below it. Anterior lobe of the membrane of the hemelytron distinctly longer than the posterior lobe. The anterior trochanter of the male with a rather narrow, pointed hook. Mesotrochanter rounded. The genitalia in both sexes like *N. mexicana* A. & S. (See Plate XI.)

Location of Types. Described from four specimens labeled, "Mexico, Nueva Leon, Santiago, April 19, 1930, 13. Creaser-Gordon." Holotype and allotype in Museum of Zoölogy, Michigan University. Paratype in Entomological Museum, University of Kansas.

Comparative Notes. This is smaller than the typical *N. mexicana* A. & M., but in the characters of the genitalia indistinguishable from it.

Notonecta robusta Hungerford 1932

(Color Plate II, fig. 14; Plate XI, figs. 4 and 10)

1932. *N. robusta* Hungerford. Jl. Kans, Ento. Soc., v, p. 54.

Size. Length (of male), a trifle less than 15 mm.; the width of pronotum, 5.1 mm.

Color. The holotype has the head, pronotum and limbs dark testaceous. The trochanters and femora marked as in other species of the *N. mexicana* A. & S. group. Scutellum black and hemelytra nearly black. No doubt this species may have hemelytra that are tan or red with black membrane.

Structural Characteristics. Anterior outline of the head, viewed from above, flattened; vertex about as long as the anterior width; margin of vertex less convex and shorter than the frontal margin of an eye; anterior breadth of vertex : synthlipsis :: 10.5:4. Pronotum about twice length of head; lateral margins divergent and nearly straight in the male; anterior angles not embracing the eyes; lateral ledge, as seen from the side, slightly undulate, upturned at both ends, oblique and shorter than the rear margin of the eye below it. Scutellum and ridge of hemelytral suture equal in length. Posterior lobe of membrane a little longer than anterior lobe. The anterior (outer) margin of the membrane constricted at the embolial suture and undulate. Anterior trochanter of male with short hook. Meso-trochanter rounded. Male genital capsule much like *N. mexicana* A. & S., but the clasper with the tip broader and the rear margin more concave. (See Plate XI, figs. 4 and 10.)

Location of Type. Described from a single male specimen which bears no locality or collector's label. Deposited in Entomological Museum, University of Kansas.

Comparative Notes. Agrees with other species of *N. mexicana* A. & S. group in having the keel of fourth ventral abdominal segment bare, the hairs confined to the sides. Head broad, eyes large and broad, rear margin broader than the length of the lateral margin of prothorax. Scutellum conspicuously broader than long. It differs from *N. lobata* Hungerford in having the last abdominal sternite of male normal in size. I have two female specimens, red and black in color, from San Cristobal, Chiapas, Mexico, A. Dampf., that are the broadest, most robust Notonecta known to me. The lateral margins of the pronotum are greatly constricted near the front so that the anterior angles flare out. The very marked undulation of the anterior (outer) margin of membrane suggests to me that these may be females of *N. robusta* Hungerford.

Notonecta ceres ceres Kirkaldy 1897

(Color Plate III, figs. 2 and 3; Plate XI, fig. 7; text figure 6)

1897. *N. mexicana* var. *ceres* Kirkaldy, Ento. Soc. London, p. 402, 1897.
1904. *N. mexicana* var. *ceres* Kirkaldy, Wiener Ento. Zeit., xxiii, p. 132.
1905. *N. mexican* var. *ceres* Kirkaldy; Bueno. Jl. N. Y. Ento. Soc., xiii, p. 159.
1917. *N. mexicana* var. *ceres* Kirkaldy; Van Duzee, catalogue of Hemiptera . . p. 454.
1925. *N. mexicana* var. *ceres* Kirkaldy; Hungerford, Can. Ento., lvii, p. 238. (Says are all females, the variety *hades* all males.)

Referring to this species, also:

1851. *N. klugii* Fieber, Rhynchotographieen, p. 475 (in part).
1897. *N. mexicana* var. *hades* Kirkaldy. Ento. Soc. London, p. 402, 1897. This is only the male of *N. ceres* Kirkaldy. See list of references above.
1901. *N. mexicana* Champion. Biol. Centr. Am. Hem.-Het., 11, p. 369, Tab. 22, figs. 6, 6a-d (in part).

Size. Length, 11 mm. to 12 mm.; width of pronotum, 4.3 mm. to 4.8 mm.

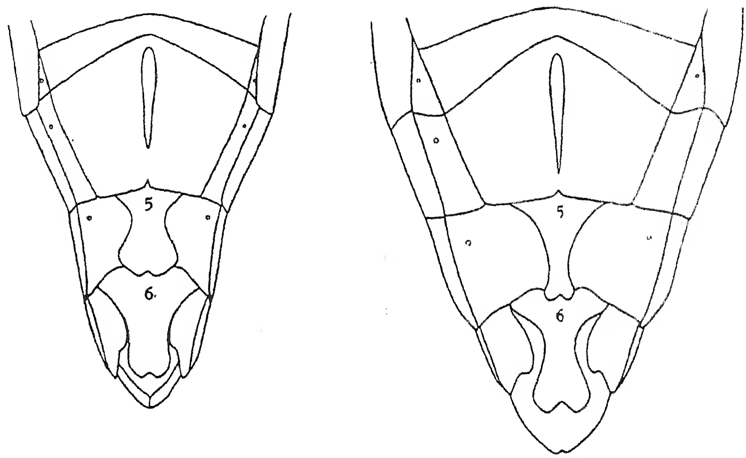
Color. Red and black, tan and black, or, in case of males, black. Anterior half of pronotum, head and limbs yellow, the middle and hind trochanters and femora with the dark stripe usual for the *N. mexicana* A. & S. group.

Structural Characteristics. Head large; anterior outline of head viewed from above, flattened; vertex a little longer than its anterior width; anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis : : 11:3. Pronotum nearly twice to twice the length of the head; lateral margins concave and moderately divergent; the margin more concave in females than in males; anterior angles slightly embracing the eyes, but rounded; lateral ledge broader anteriorly in the female than in the male, as seen from the side, strongly curved, pronounced on anterior half, only a ridge and curved on posterior half; margin of prothorax shorter than the rear margin of the eye below it. Anterior lobe of membrane of hemelytra a little longer than the posterior one. Anterior trochanters of male with moderate hook. Mesotrochanters rounded. The carina of fourth abdominal sternite bare. The terminal abdominal sternite of female narrow, broader at tip, which is broadly incised. First pair of gonapophyses short. Male genital capsule as shown on Plate XI.

Location of Types. In the Kirkaldy collection at U. S. N. Museum at Washington.

Comparative Notes. Described by Kirkaldy as a variety of *N. mexicana* A. & S., but really a distinct species. Kirkaldy described the red and black females as *N. mexicana* var. *ceres* and the black

males as *N. mexicana* var. *hades*. I have pointed out previously that these are a single species. This species is smaller than *N. mexicana* A. & S. and a trifle larger than *N. hoffmanni* Hungerford. It is distinguished from the former by the less acute anterior angles of the prothorax and from the latter by having the lateral margins of prothorax concave.



TEXT FIGURE 6. *Notonecta ceres stirtoni* Hungerford and *N. ceres ceres* Kirkaldy. Underside of abdomen of females. (Subgenus Erythronecta.)

Data on Distribution. Costa Rica: San Jose, C. R. 1160 M. August, 1905, P. Biolley.; La Palma, 1600 M. P. Biolley (Det. by Kirkaldy as var. of *N. mexicana*); Rio Sarapiqui, Alt. 2,000 m. Heinrich Schmidt; Rio. Virilla, December 26, 1931, Heinrich Schmidt; R. Susio, H. Rogers.

Notonecta ceres stirtoni new subsp.

(Text figure 6)

1928. *N. mexicana* var. *ceres*, Kirkaldy; Hungerford, Pan. Pac. Ento., iv, No. 3, p. 119. (Taken mating with var. *hades*.)

In this subspecies the lateral margins of the prothorax of the male are almost straight as seen from above. In the female the penultimate sternite projects broadly in the middle, whereas in *N. ceres* Kirk. the portion of the sternite surpassing the segment is narrow.

Location of Types. Francis H. Snow Coll. From El Salvador, C.A.

Notonecta ceres rogersi Hungerford, 1932

(Color Plate II, fig. 12)

1932. *N. rogersi* Hungerford, Jl. Kansas Ento. Soc., v. p. 55.

This subspecies is larger than the typical form. The male clasper is almost identical with *N. ceres* Kirk. When I described this species I was confusing *N. ceres stirtoni* with *N. ceres* Kirkaldy. I have one female which I assign to this subspecies. In this red and black specimen the lateral margins of pronotum are constricted in front of the middle instead of near the middle as in typical *N. ceres* Kirkaldy.

Notonecta impressa Fieber, 1851

1851. *N. impressa* Fieber, Rhynchotographieen Abh. Böhm. Gesel. Wis. (5), vii, p. 475.

1897. *N. impressa* Fieber; Kirkaldy, Trans. Ento. Soc. London, 1897, p. 403 (Made it a synonym of *N. insulata* Kirby in error).

1901. *N. impressa* Fieber; Champion, Biologia Centr. Americana, Rhynchota, ii, p. 368 (Places doubtfully under *N. mexicana* A. & S. in error).

1908. *N. impressa* Fieber; Kirkaldy and Bueno, Proc. Ento. Soc. Washington, x, p. 198 (Places as syn. of *N. insulata* Kirby in error).

1917. *N. impressa* Fieber; Van Duzee, Cat. of Hemiptera of America, p. 453.

1925. *N. impressa* Fieber; Hungerford, Can. Ento., lvii, p. 241 (Says not *N. insulata* Kirby).

Size. Female nearly 14 mm. long.

Shape. Much like *N. montezuma* Kirkaldy; eyes less prominent; pronotum transversely crossed by a strong depression that does not extend to the margins.

Color. A red and black species. The head and limbs of usual color; scutellum black; hemelytra red with black markings such as in *N. montezuma* Kirkaldy.

Structural Characteristics. Head not prominent; the face deeply depressed with surface transversely wrinkled; a longitudinal ridge extending from the depression to the labrum; anterior margin of vertex : synthlipsis :: 6.7 : 2.7. Pronotum and head sloping downward. Scutellum large. Hemelytral suture short. Mesotrochanter rounded. Ventral abdominal keel without hairs on the ridge. Last abdominal sternite of female broad, short and depressed on the sides.

Location of Type. In the Zoölogical Museum at Berlin I found a female specimen labeled, "*Notonecta impressa*" "3623, a green label "Mexico Westw.," a green label "Impressa Fieb." This fits Fieber's description exactly! The head is not prominent. The synthlipsis : anterior margin of vertex :: 2.7 : 6.7, as seen from above with the body horizontal. The pronotum slopes downward, and the head follows the same slope; the face is deeply depressed, the surface of the depression uneven and transversely wrinkled. Below the depression there is a median longitudinal ridge to the labrum;

transverse wrinkles across this part of the face; labrum cross-wrinkled. The pronotum is tranversely crossed just in front of the middle by a depression that does not extend to the margins of the pronotum, which are straight. The anterolateral angles embrace the eyes; lateral margins are moderately ledged. Mesotrochanter is rounded; ventral abdominal keel is without hairs on the ridge. The comparative longitudinal measurements from above are as follows: Head : Pronotum : Scutellum : Hemelytral suture (from tip of scutellum) : tip of hemelytral suture to wing tip :: 2.5 : 4.9 : 5.7 : 3.7 : 10+.

Comparative Notes. The color is quite like *N. montezuma* Kirkaldy, but it is a little smaller than the female *N. montezuma* Kirkaldy from Valentine, Texas, with which I compared it. The eyes seem smaller and the pronotum embraces the eyes a little more. The eyes seem flatter on top and the transverse pronotal depression more marked. The shape of the last ventral abdominal plates is the same in both females. While I am retaining *N. montezuma* Kirkaldy as a separate species, an examination of a long series may discover specimens like Fieber's female. Since *N. montezuma* Kirkaldy in the Hope Collection came from the Westwood Collection, according to information given by Professor Poulton to Mr. Champion, instead of "West Mexico" as Kirkaldy recorded, there is additional doubt about Kirkaldy's species being specifically different from Fieber's.

N. impressa Fieber is not *N. compacta* Hungerford, which also has transversely depressed pronotum. My *N. compacta* has sides of pronotum strongly constricted, *N. impressa* Fieber does not. It is not *N. mexicana* A. & S., because the lateral edge of the prothorax of *N. impressa* Fieber is straight and the ledge is even and longer, the pronotum longer, head smaller, scutellum very large, and the hemelytral suture short. *N. impressa* Fieber is not *N. kirbyi* Hungerford, which has a much wider synthlipsis.

Notonecta montezuma Kirkaldy, 1897

(Color Plate II, fig. 1; Plates X, fig. 2, and XV fig. 4.)

1897. *N. montezuma* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 402.

1901. *N. montezuma* Kirkaldy; Champion, Biol. Centrali Americana Heteroptera, vol. II, p. 369, pl. 22, figs. 8 and 9.

1904. *N. montezuma* Kirkaldy, Wien. Ento. Zeit., xxiii, pp. 94 and 132.

1905. *N. montezuma* Bueno, Jl. N. Y. Ento. Soc., xiii, p. 162. (Records specimen from California in error.*)

* The specimen labeled "California" in the American Museum, and determined by Bueno as *N. montezuma* Kirk., is an oriental species with erroneous locality label.

1919. *N. montezuma* Kirkaldy; Hungerford, Kansas Univ. Sci. Bull., xi, pp. 168, 172 and 331.

1923. *N. montezuma* Kirkaldy; Hungerford, Kansas Univ. Sci. Bull., xiv, p. 426.

1928. *N. montezuma* Kirkaldy; Hungerford, Annals Ento. Soc. Am., xxi, p. 142, pl. ix, fig. 8. (Fig. male genital capsule and records species from Valentine, Texas.)

Size. Length, 14 mm.-15 mm.; width of pronotum, 4.8 ± mm.

Shape. A rather elongate species.

Color. A red and black species. Head and legs of usual color, often marked with green. Pronotum often having a median dark spot a little behind the anterior margin. Scutellum black. Hemelytra orange-red with black markings; the clavus may be marked with dark spots, especially at the tip where they join and form a part of an irregular black band that traverses the corium at this level; membrane black. Venter dark except the sides of prothorax beneath the ledge, the distal end of the metacoxal shields (extension of mesothoracic scutellum according to Rich 1918), the connexivum and median abdominal keel which are usually lighter in color.

Structural Characteristics. Anterior outline of the head viewed from above, rather flattened; face transversely depressed; vertex longer than its anterior width; anterior margin of vertex less convex and shorter than the anterior margin of an eye; anterior breadth of vertex : synthlipsis :: 8:3 (a little more or less); head a little more than half as long as pronotum. Lateral margins of pronotum only moderately divergent and straight; anterolateral angles somewhat embracing the eyes; lateral ledge, as seen from the side, nearly straight, faintly sigmoid and somewhat oblique, slightly longer than the rear margin of the eye below it. Scutellum large, longer than the pronotum. Hemelytral suture short, the ridge of the hemelytral suture shorter than the scutellum. Anterior lobe of membrane longer than the posterior lobe. Anterior trochanter of the male with a black pointed tubercle directed only slightly forward in place of the hook. Mesotrochanter rounded. Anteapical tooth of middle femur normal. Ventral abdominal keel smooth and thickened down the entire length of the fourth and fifth segments and a smooth space down the middle of the following segment. The terminal abdominal sternite of female short, broad and depressed on the sides. First pair of gonapophyses of female intermediate in length. Male genital capsule as shown in Plate XV, fig. 4.

Location of Types. Male and female in Hope Collection at Oxford, England. I find, upon examining the types, that Doctor Champion's descriptive notes and figures are excellent.

Data on Distribution. "W. Mexico" does not mean West Mexico,

according to Professor Poulton, but simply that specimens are from Westwood's collection.

In 1928 I recorded 11 specimens taken by the University of Kansas party as follows: 10 specimens, Valentine, Texas, July 13, 1927, R. H. Beamer. One specimen, Presidio County, Texas, July 16, 1927, R. H. Beamer. Another, Alpine, June 5, 1927 (U. S. N. M.). I have also two male specimens taken by Hobart Smith near Santa Rosa, Guanajuata, Mexico, August 14, 1932. In the Stockholm Museum there is a male labeled "Mexico" "Sallé." I have also seen the specimen in the Paris Museum labeled "Nord de l'Inde 39-42" which was mentioned by Kirkaldy. The locality is indeed erroneous.

Notonecta insulata Kirby, 1837

(Color Plate III, fig. 1; Plate XV, fig. 1.)

1837. *N. insulata* Kirby, *in* Richardson's Faun. Bor. Am., iv, p. 285.

1878. *N. insulata*, Kirby; *in* Bethune reprint, p. 140; same from Can. Ento., x, p. 216.

1851. *N. insulata* Kirby; Fieber, Rhynchotographieen, p. 479.

1851. *N. insulata* Kirby; Fieber, Rhynchotographien, p. 55 (Van Duzee's Catalogue.).

1876. *N. insulata* Uhler; Bull. U. S. Geol. Geog. Surv. II, p. 73. (Remarks about Baltimore, Md., specimens refer to this species.)

1878. *N. insulata* Kirby; Uhler, Proc. Boston Soc. Nat. Hist., xix, p. 442, "No. 17 Harris' Collection July 1, 1823."

1894. *N. insulata* Kirby; Van Duzee, Bull. Buffalo Soc. Nat. Sci., v, p. 186. (Not uncommon in stagnant pools with clayey bottom.)

1897. *N. insulata* Kirby; Kirkaldy, Trans. Ento. Soc. London for 1897, p. 403 (in part).

1899. *N. insulata* Kirby; Smith, Insects of N. J., p. 144.

1902. *N. insulata* Kirby; Bueno, Jl. N. Y. Ento. Soc., x, pp. 230, 231, 232, 235.

1904. *N. insulata* Kirby; Kirkaldy, Wien. Ento. Zeit. xxiii, pp. 94 and 132.

1905. *N. insulata* Kirby; Bueno, Jl. N. Y. Ento. Soc., xiii, pp. 46, 150 and 162. Pl. vii, fig. 9 (in part).

1908. *N. insulata* Kirby; Bueno, Jl. N. Y. Ento. Soc., xvi, p. 237.

1909. *N. insulata* Kirby; Kirkaldy & Bueno. Proc. Ento. Soc. Wash., x, p. 198 (in part).

1910. *N. insulata* Kirby; Bueno, Jl. N. Y. Ento. Soc., xviii, p. 33.

1910. *N. insulata* Kirby; Smith, catalogue Ins. N. J., edn. 3, p. 169.

1913. *N. insulata* Kirby; Browne, Jl. Exp. Zoöl., xiv, p. 61.

1914. *N. insulata* Kirby; Parshley, Psyche, xxi, p. 140. (Taken on April 27, Orono, Maine.)

1917. *N. insulata* Kirby; Parshley, Occ. papers Boston Soc. Nat. Hist., vii, p. 113.

1917. *N. insulata* Kirby; Van Duzee, Catalogue Hemiptera, p. 453 (in part).

1917. *N. insulata* Kirby; Hungerford, Ento. News, xxviii, p. 175.

1918. *N. insulata* Kirby; Hungerford, Ento. News, xxix, pp. 242-244, Pl. xiv, fig. 5 (oviposition of).

1919. *N. insulata* Kirby; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 168, 173, 181, 182, 186, 187, 189. Pl. viii, figs. 3 and 4 (eggs) Pl. xix, figs. 3, 4, 7. (1st instar nymph.)

1919. *N. insulata* Kirby; Hungerford, Kans. Univ. Sci. Bull., xi, p. 332, Pl. xxxi, fig. 9 (male genital capsule).

1919. *N. insulata* Kirby; Parshley, Occ. papers Mus. Zoöl. Univ. Mich. No. 71. (From Vancouver Island, probably *N. kirbyi* Hungerford.)

1923. *N. insulata* Kirby; Bueno & Hussey, Bull. Brookl. Ento. Soc., xviii, p. 107.

1923. *N. insulata* Kirby; Bueno, Conn. St. Geol. & Nat. Hist. Survey Bull. No. 34, pp. 405 and 407. Pl. xvi, fig. 8 (Mar. & Apr.).

1926. *N. insulata* Kirby; Leonard, Cornell Univ. Agri. Exp. Sta. Memoir 101, p. 139. (March to November.)

1926. *N. insulata* Kirby; Blatchley, Heteroptera . . . p. 1052 (in part).

1926. *N. insulata* Kirby; Hungerford, Bull. Brookl. Ento. Soc., xxi, p. 195.
1929. *N. insulata* Kirby; Hutchinson, Annals S. Afr. Mus., xxv, pt. 3, p. 364.

Referring to this species, also:

1851. *N. rugosa* Fieber, Rhynchotographieen, pp. 476-477 and his varieties *bicolor*, *plagiata* and *cordigera* from eastern U. S. but not his *basalis* from Brazil.
1897. *N. impressa* Kirkaldy (not Fieber) Trans. Ento. Soc. London for 1897, p. 403.
1897. *N. insulata* Kirkaldy, Trans. Ento. Soc. London for 1897, p. 404. His varieties *odora* and *geala*.
1917. *N. insulata* var. *geala* Kirkaldy; Van Duzee, Catalogue Hemiptera, p. 453.
1917. *N. insulata* var. *odora* Kirkaldy; Van Duzee, Catalogue Hemiptera, p. 453.

Size. Length, 14 mm. to 15.5 mm.; width of pronotum, 4.5 mm. to 5 mm.

Shape. A large and rather elongate species.

Color. Pattern variable, and described by Kirkaldy under five varieties, but all intergradations occur. Some specimens are nearly immaculate; gray to light tan, but with the caudal half of pronotum darkened by black mesonotum beneath; scutellum black and a streak behind hemelytral suture infuscated; golden hairs present, especially on the corium. Other specimens are strikingly marked, the hemelytra being gray, tan and black with many individuals showing some roseate reflections, this last especially marked on freshly captured specimens. While many specimens are marked like the typical *N. glauca* L., the following may be given as the typical color pattern: Head and anterior half of pronotum grayish to testaceous, often marked with green. Limbs testaceous, often greenish, with dark coxæ; hind femora longitudinally streaked beneath. Venter dark except connexivum which is more or less testaceous, often greenish. Posterior half of pronotum darkened by the black mesonotum beneath it. Scutellum black. Hemelytra with clavus gray or tan except at tip, which is spotted with black; corium with black or brown maculations near base and often along the margin, a transverse black band, broadening laterally, starting from end of hemelytral suture, behind which is a tan or roseate, roughly triangular spot, that is quite characteristic for the species; membrane and distal angle of corium dark; membrane near the tip may be traversed by a testaceous or tan band; corium and anterior lobe of membrane especially, clothed with golden hairs. Dorsum of abdomen more or less orange, metaxyphus typically yellow.

Structural Characteristics. Head about one-half length pronotum, transverse; vertex slightly longer than its anterior width; anterior margin of vertex less convex, plainly shorter than the frontal margin of the eye and projected beyond it; anterior breadth of vertex : synthlipsis :: 2—:1; synthlipsis usually slightly less than one-half

width of the eye. Pronotum about twice the length of the head; lateral margins only moderately divergent, nearly straight; anterior angles normal; lateral ledge narrow, nearly straight and but slightly oblique. Anterior lobe of membrane slightly longer. Anterior trochanters of male with a small hook beyond the middle. Mesotrochanter not angulate. Carina of the fourth ventral abdominal segment bare on keel. The terminal abdominal sternite of female broad, short and only slightly incised at tip. Female gonapophyses (first pair) of intermediate length. Male genital capsule as shown on Plate XV.

Location of Type. This species was described from a single specimen. I have failed in my endeavor to locate this type.

Comparative Notes. This species in certain particulars appears to be a connecting link between the subgenera Notonecta and Paranecta, as pointed out by Hutchinson (1929). It is one of our largest American species. Its American relatives are *N. kirbyi* Hungerford long confused with it, and *N. montezuma* Kirkaldy. While this species is often found in collections with *N. undulata* Say, it is readily distinguished by its larger size. The last abdominal sternite of the female is but shallowly incised at tip, while it is deeply incised in *N. undulata* Say. The male genital capsules are quite different also.

Data on Distribution. The distribution given in Van Duzee's catalogue embraced, of course, *N. kirbyi* Hungerford. Its true range appears to be the states north of the fortieth degree of latitude and east of the one hundredth meridian and the region of Canada adjacent thereto.

The records based upon my own observations are:

UNITED STATES OF AMERICA

MAINE: Maine (Ohio State Univ.)

NEW YORK: Ithaca, April 29, 1926; July 17, 1917, H. B. Hungerford; Albany, April, 10, 1886 (Uhler Coll.); White Plains, August 22, 1907 (U. S. N. M.); Long Island, H. Meeske (U. S. N. M.); Staten Island, September 3, 1926 (U. S. N. M.); West Point, September 9, 1917, W. Robinson; also, April 22, 1926 (U. S. N. M.); Lake Side (N. Y.?), September 22, October 18, November 16 (Uhler Coll.)

NEW JERSEY: Madison (Uhler Coll.); Palisades, August 3, 1923 (U. S. N. M.).

CONNECTICUT: Hartford, October, 1892. (U. S. N. M.); Milford, March 21; New Canaan, April 3, 1919 (see Conn. Geol. & Nat. Hist. Surv. Bull. 34).

MASSACHUSETTS: Woods Hole (U. S. N. M.); Wellesley, October 10 (Uhler Coll.).

MARYLAND: Mt. Zion Valley, August 16 (Uhler Coll.).

OHIO: Cuyahoga Co., June 1, 1912, C. J. Drake.

MICHIGAN: Cheboygan Co., August 7, 1930, July 20, 1930; Douglas Lake, Cheboygan Co., July 29, 1928, July 26, 1926; Pellston Rd. Pool, July 20, 1930. The same pool, August 3, 1932; Mackinac Island State Park, August 19, 1925. All taken by H. B. Hungerford; Ann Arbor, March 7, 1894, Wolcott (Nebr. U.).

MINNESOTA: Grand Marais, August 13, 1922; Pelican Rapids, August 22, 1922. Itasca Park, Green Lake, August 21, 1922. St. Louis Co., August 14, 1922. All taken by H. B. Hungerford.

CANADA

NEWFOUNDLAND: Kelligrews, August 26, 1922, F. Johansen; (Ottawa, Can.).

QUEBEC: Knowlton, July 30, 1929, L. J. Milne (newly emerged); (Ottawa, Can.).

ONTARIO: E. Ottawa, May 12, 1930, G. S. Walley. (Ottawa, Can.)

Other Biological Notes. Long ago Doctor Uhler pointed out that this insect prefers cool waters. Van Duzee has reported it in stagnant pools having clayey bottoms near Buffalo, N. Y. I found it a rather rare insect around Ithaca, N. Y., but in Michigan, in a gravel-pit pool, I took seventy-six specimens in a couple of hours. This pool contained cold water about two feet deep at the west end and shallower and warmer water elsewhere. Most of the specimens were taken in the cold water, where they were swimming slowly on an even keel about midway between the bottom and top. They are able to remain for a long time submerged, their backs covered with a silvery film of air. At Ithaca, N. Y., the species wintered as an adult; eggs were attached to submerged vegetation during the last of April and in May. The incubation period was twenty-four days.

Notes on *Notonecta rugosa* Fieber

In the Zoölogical Museum at Berlin there are nine specimens in the row labeled *N. rugosa* Fieb. They are labeled as follows:

First: "3628" "Baltim. Klug." "Rugosa Fieb." The last looks like Fieber's writing.

Second: "Cat. No. 3628" "Nov. Granada-Gond" (I cannot be sure of this written label.) "*Notonecta rugosa* Fieb. and below it another "*rugosa* Fieb. *undulata* Say."

Third: "Cat. No. 3628" and a green label I cannot read with certainty. "Massachut. Zim."? *Notonecta rugosa* Fieb."

Fourth: Cat. No. 3628" "Massachus. Zimmerm" *Notonecta rugosa* Fieb.

Fifth: Labeled as above. This is a darker specimen than the four above.

Sixth and Seventh: Labeled as above.

Eighth: "3629" "Mexico Deppe" "*Notonecta rugosa* var."

Ninth: "3630" "Baltim. Klug." "*N. rugosa* var." This is a white specimen.

All of the above except No. 8 are *N. undulata* Say, and the first specimen looks as if it were Fieber's determination label. The eighth one is a dermestid-eaten female. It is not *N. undulata* Say, but I do not know what to call it.

Doctor Fieber described his *N. rugosa* as "Länge, 7⅓-7½ linien." The specimens here in Berlin are only 5½ English lines. Doctor Kirkaldy places *N. rugosa* Fieb. as a synonym of *N. insulata* Kirby, no doubt being influenced by Fieber's name and by his statement of length. Fieber named four varieties: variety *bicolor* and variety *plagiata* from "Longisland, Baltimore (Mus. Berol. und Hal.)," var. *cordigera* from "Pennsylvanien (Dr. Germar), Baltimore (Mus. Berol.)," and var. *basalis* from "Brazilien (Mus. Berol.)." In Kirkaldy's Uber Notonectiden, p. 94, he says that Doctor Breddin sent him from the Halle Museum a specimen labeled *N. rugosa*, but that it was a variety of *N. undulata* Say and too small to be Fieber's *N. rugosa*.

I have seen no species from Brazil (except *N. nigra* Fieb.) that is as large as *N. insulata* Kirby. Doctor Fieber recorded his var. *basalis* as from Brazil. I did not find it in the Vienna Museum. *N. rugosa* Fieber is either a synonym of *N. insulata* Kirby credited with the same size or else is *N. undulata* Say with some strange error in Fieber's measurement. In any event, the localities in eastern United States are so well known that *N. rugosa* must be one or the other of the species named above.

Notonecta kirbyi Hungerford, 1925

(Color Plate III, fig. 4; Plate XV, fig. 2)

1925. *N. kirbyi* Hungerford, Can. Ento. lvii, p. 241, pl. 6, fig. 2.
1928. *N. kirbyi* Hungerford, Annals Ent. Soc. Amer., xxi, p. 142.
1928. *N. kirbyi* Hungerford, Ento. News, xxxix, p. 156.

Referring to this species, also:

1875. *N. insulata* Uhler; Wheeler's Rept. upon Geog. & Geol. Expl. and Surveys West of One Hundredth Meridian, Washington, vol. v, ch. xii, p. 841. (Owen's valley, Calif., by F. Bischoff.)

1876. *N. insulata* Uhler, Bull. U. S. Geol. Geog. Surv., vol. I, Bull. No. 5, 2d ser. p. 339 (Mts. of Colorado).

1876. *N. insulata* Uhler, Bull. U. S. Geol. Geog. Surv., p. 73. (Reprint from above.)

1877. *N. insulata* Uhler, Wheeler's Rept. Chief Engineer for 1877, p. 1332. (In Arizona.)

1878. *N. insulata* Uhler, Bull. U. S. Geol. Geog. Surv., iv, p. 509. (Milk river region, Montana.)

1897. *N. insulata* var. *impressa*, Kirkaldy (not Fieber) Trans. Ento. Soc. London for 1897, p. 404.

1901. *N. insulata* Champion, Biol. Centr. Amer. Hem.-Het., II, p. 369.

1904. *N. insulata* Uhler., Proc. U. S. Natl. Mus., xxvii, p. 364.

1905. *N. insulata* Bueno, Jl. N. Y. Ento. Soc., xiii, p. 46 (in part).

1906. *N. insulata* Snow, Trans. Kansas Acad. Sci., xx, pt. 1, p. 181.
1909. *N. insulata* Kirkaldy and Bueno, Proc. Ento. Soc. Wash, x, p. 198 (in part).
1914. *N. insulata* Van Duzee, Trans. San Diego Soc. Nat. Hist. II, p. 33.
1917. *N. insulata* Van Duzee, Catalogue Hemiptera, p. 453 (in part).
1919. *N. insulata* Parshley, Occas. Papers Mus. Zoöl. Univ. of Mich., No. 71, 1919. (Probably.)
1922. *N. insulata* Hungerford, Kansas Univ. Sci. Bull., xiv, pp. 417-419.
1922. *N. insulata* Parshley, S. Dakota St. College Tech. Bull. No. II, p. 22 (from Capa, Jones Co., S. D.)

Size. Length, 13.8 mm. to 15.5 mm.; width of pronotum, 4.5 mm. to 4.8 mm.

Shape. A rather elongate species.

Color. Variable. Some specimens nearly like *N. insulata* Kirby, but usual pattern considerably darker; limbs usually less distinctly longitudinally striped. Typical color pattern tan and black or red and black. The clavus and basal half of corium tan, orange or red mottled more or less with black. Distal half of corium and basal three-fifths of membrane typically black, the black field of the corium broken only by two small spots colored like the clavus. (These spots may be large and confluent giving a triangular patch like that of *N. insulata* Kirby.) Corium and anterior lobe of membrane especially clothed with golden hairs. Dorsum of abdomen in the red forms nearly always reddish; metaxyphus typically black. The venter dark except connexivum.

Structural Characteristics. Head less than one-half length of pronotum, transverse; vertex longer than its anterior width; anterior margin of vertex less convex, as long as the frontal margin of the eye and projected beyond it; anterior breadth of vertex : synthlipsis :: 2 — : 1; synthlipsis usually fully one-half to two-thirds width of an eye. Pronotum more than twice as long as the head; lateral margins only moderately divergent, nearly straight; anterior angles normal or slightly embracing the eye; lateral ledge a little thicker than in *N. insulata* Kirby, oblique and slightly sigmoid. In side view the rear portion of pronotum more elevated than in *N. insulata* Kirby. Anterior lobe of membrane slightly longer. Anterior trochanter of male with a small hook beyond the middle. Mesotrochanter not angulate. Carnia of the fourth ventral abdominal segment bare on keel. The terminal abdominal sternite of female broad, short and only slightly incised at tip. Female gonapophyses (first pair) of intermediate length. Male genital capsule as shown on Plate XV.

Location of Type. In the Francis Huntington Snow Entomological Museum at the University of Kansas. Holotype, allotype and paratypes from Emery county, Utah, Aug.-Sept., 1921, Mrs. Grace Wiley.

Comparative Notes. This species has long been confused with *N. insulata* Kirby, from which it can be distinguished as indicated in the key.

Data on Distribution. This species has been confused heretofore with *N. insulata* Kirby. The distribution is western United States and Canada. I have the following records:

CANADA

BRITISH COLUMBIA: Mt. Cheam, Mar. 9, 1924; Bearfoot Mt., Sept. 3, 1917 (U. S. N. M.); Vernon, Aug. 5, 1931, L. D. Anderson; Vernon, Sept. 26, 1929 (Ottawa, Can.); Peachland, Oct. 7, 1921, A. N. Gartrell; Rolla, Aug. 6, 1927, P. N. Vroom; Revelstoke Mt., 6,000 ft., Aug. 12, 1923, E. R. Buckell; Creston, July 15, 1926, A. A. Dennys; Princeton, May 6, 1923, P. N. Vroom; Brents L. Summerland, Oct. 29, 1931, A. N. Gartrell; Copper Mts., Oct. 26, 1928, G. Stace Smith; Oliver, July 24, 1923, E. R. Buckell; Minnie L., July 26, 1925, N. Criddle; Aspen Grove, May 26, 1922, P. N. Vroom; (above in Ottawa, Can.).

ALBERTA: Tofield, Aug. 25, 1923, E. H. Strickland; Cypress Hills, July 21, 1930, J. H. Pepper; Waterton Lakes, July 2, 1930, J. H. Pepper; Medicine Hat, Aug. 7, 1929, J. H. Pepper.

UNITED STATES OF AMERICA

S. DAKOTA: Capa, Jones Co., June 1, 1921, H. C. Severin (S. D. St. College).

NEBRASKA: Monroe Canyon, Sioux Co., August 15, 1908, J. T. Zimmer (Nebr. U.); Pine Ridge, July (Ohio St. Univ.).

COLORADO: Pingree Park, Aug. 25, 1921, Lawson & Beamer; Northern Colo., Aug. 25, 1920, R. C. Moore; Caisson, July 1, 1931, L. D. Anderson; Colorado 819 (Uhler Coll.); Colorado Mts., July to Sept. (Uhler Coll.); Colorado 2063 Gillette (Uhler Coll.); Denver, B. H. Smith (Uhler Coll.); Colorado, C. F. Baker (U. S. N. M.); Hamilton, July 3, 1928 (newly emerged); Ft. Collins, Aug. 7, 1900, Aug. 11, 1899, Sept. 1, 1926, Sept. 8, 1926, Sept. 14, 1916, Sept. 18, 1928, Sept. 19, 1931, Oct. 2, 1917, Oct. 5, 1931, Oct. 30, 1930, Nov. 1, 1926 (Ft. Collins Exp. Sta.).

TEXAS: Valentine, July 13, 1927, R. H. Beamer; Presidio, July 16, 1927, R. H. Beamer.

NEW MEXICO: Torrance Co., July 21, 1929, P. W. Oman; Estancia, Sept. 6, 1929, C. H. Martin; Cocorro Co., Aug. 18, 1927, R. H. Beamer; Messilla Park, July 18, 1927, L. D. Anderson; Las Vegas, Barber & Schwarz (U. S. N. M.).

ARIZONA: Yavapai Co., July 1, 1929, L. D. Anderson; Cochise Co., July 20, 1927, R. H. Beamer; Gila Co., Aug. 5, 1927, R. H. Beamer; Santa Cruz, Aug. 7, 1927, P. A. Readio; Santa Rita Mts., July 25, 1927, R. H. Beamer; Navajo Co., Aug. 15, 1927, R. H. Beamer; Coconino Co., Aug. 13, 1927, P. A. Readio; Douglas, San Bernardino Ranch, 3,700 ft., Aug., F. H. Snow; Baboquivaria Mts., F. H. Snow; Arizona (Uhler Coll.); Yuvapai Co. (U. S. N. M.); Senator Mine, near Prescott, Sept. 12, 1907; Flagstaff, Barber & Schwarz (U. S. N. M.); Lowell (Uhler Coll.); Chiricahua Mts., Pinerey Canyon, Boy Scout Camp, June 17, 1932, D. K. Duncan; Reservation Springs, 12 miles N. E. of Globe, Sept. 17, 1932, D. K. Duncan; Peach Springs, Aug. 27 (Ohio State Univ.).

UTAH: Emery Co., Aug. 2, 1921, Grace O. Wiley; Emery Co., July 22 and 29, 1921, Grace O. Wiley; Emery Co., Sept. 13, 1921, Grace O. Wiley; Farwest, C. J. D. Brown; Salt Lake Co., July, 1929; Kane Co., Summer, 1921, R. C. Moore; Garfield Co., Aug. 14, 1921, R. C. Moore; Antelope, July 1, 1931, L. D. Anderson; Ogden, June 27, 1910, F. T. Moore (U. S. N. M.); Salt Lake (U. S. N. M.); Lehi, May 27, 1930, G. F. Knowlton (Knowlton Coll.).

NEVADA: Sunnyside, C. T. Brues, 1930, Hot Sp. Exp., 1930, Sp. No. 97; Bottle Mountain; Fallon, Aug. 9, 1929, L. D. Anderson; Carson City, Aug. 9, 1929, R. H. Beamer; Meadow, Nev. Hot Sp. Expd., 1930, Sp. No. 113, Gerlach & Soldier; Reno, Feb. 13, 1916, H. G. Dyar (U. S. N. M.); Owens Valley (Uhler Coll.); Vacity (Uhler Coll.).

CALIFORNIA: Bautista Canyon, Apr. 8, 1931, C. H. Martin; Emery, May 14, 1921, C. T. Dodds; Oakland, Feb. 22, 1921, C. T. Dodds; Laguna Beach, C. T. Dodds; Laguna Mts., July 6, 1929, P. W. Oman; Alpine, July 9, 1929, L. D. Anderson; San Diego Co., July 28, 1929, P. W. Oman; Cuyamaca Lake, July 6, 1929, P. W. Oman; Giant Forest, July 28, 1929, P. W. Oman; Indio, July 24, 1929, L. D. Anderson; Palo Alto, Mar. 5, 1892 (Cornell); Giant Forest, Seq. Nat. Park, July 21, 26, 1907, 6,000-7,000 ft., J. C. Bradley (Cornell); Fish Springs, Hot. Sp. Expd., 1930, C. T. Brues; San Francisco (labeled by Uhler *N. impressa* Fieb.) (Uhler Coll.); San Luis Obispo (U. S. N. M.); Sonoma Co., (U. S. N. M.); San José, Sept. 8, 1881 (U. S. N. M.); Menlo Park, Jan. 1905, F. Hornung; Santa Barbara Co., Coquillet (U. S. N. M.); San Diego Co., Coquillet (Uhler Coll.); California, Aug., C. V. Riley (Uhler Coll.); California, L. Lethierry (labeled *N. mexicana*) (U. S. N. M.); Santa Clara Co., Baker (U. S. N. M.); Placer Co., Aug. (U. S. N. M.); Palm Springs, H. G. Hubbard (U. S. N. M.); Mt. Diablo (U. S. N. M.); S. California (Uhler Coll.); San Antonio Canyon, Ontario, July 25, 1907; Campo, Calif., Laguna Mts., Aug. 25, 1932, H. W. Capps.

OREGON: Gaston; Corvallis, Sept. 4 (C. J. Drake); Dilley (H. G. Barber); Hood River, July 17, 1931, L. D. Anderson; Boardman, July 17, 1931, L. D. Anderson; Union, July 13, 1931, L. D. Anderson; Hot Lake, July 13, 1931, L. D. Anderson; Oregon (Uhler Coll.); Corvallis, Aug. 8, 1925 (U. S. N. M.); Mt. Hood Lodge, Parkdale, alt. 3,500 ft., July 30, 1931, M. C. Lane (U. S. N. M.); Warner Lake, 1877 (Uhler Coll.).

WYOMING: Yellowstone Nat. Park, Aug. 2, 1926, George Cady; Grand Teton Nat. Park, Aug. 8, 1931, L. D. Anderson; Ft. Laramie, Horn (Uhler Coll.); Grand Teton Nat. Park, Aug. 1931, L. D. Anderson.

IDAHO: Burley, July 6, 1931, L. D. Anderson; Bliss, July 7, 1931, L. D. Anderson; Soldier, (Nebr. U.); Council, June 25, 1926, alt. 3,059 ft.; Moscow, Oct. 1928, alt. 2,560 ft.

WASHINGTON: Pullman; L. McElroy, Paha, 1920; Kalama, July 21, 1931, L. D. Anderson; Coulee City, Sept. 2, 1920, M. C. Lane (U. S. N. M.); Lind, May 13, 1921, M. C. Lane (U. S. N. M.); Stratford, Sept. 3, 1920, M. C. Lane (U. S. N. M.); Ritzville, May 17, 1921, M. C. Lane (U. S. N. M.); L. McElroy, Paha, June, 1920, M. C. Lane (U. S. N. M.); Pullman, C. V. Piper (U. S. N. M.).

MONTANA: Glacier Park, Aug. 20, 1926, George Cady; Anaconda, Aug. 12, 1931, L. D. Anderson; Whitehall, Aug. 31, 1931, L. D. Anderson; Three Forks, July 7, 1931, L. D. Anderson.

Notonecta irrorata Uhler, 1879

(Color Plate I, fig. 1; Plates X, fig. 4, and XVI fig. 1.)

1879. *N. irrorata* Uhler, Proc. Boston Soc. Nat. His., xix, p. 443.

1888. *N. irrorata* Uhler; Provancher, Pet. Faune Ento. Can., iii, p. 200.

1891. *N. irrorata* Uhler; Summers, Bull. Agr. Exp. Sta., Univ. of Tenn., iv, No. 3, p. 82.

1894. *N. irrorata* Uhler; Van Duzee, Bull. Buf. Soc. Nat. Sci., v, p. 186. (Not infrequent in stagnant, muddy pools about Buffalo, N. Y.)

1897. *N. irrorata* Uhler; Kirkaldy, Trans. Ento. Soc. Lond. for 1897, p. 418.

1900. *N. irrorata* Uhler; Osborn, Contr. Dept. Zoöl & Ent. Ohio St. Univ, No. 2 p. 79.

1902. *N. irrorata* Uhler; Bueno, Jl. N. Y. Ento. Soc., x, pp. 230, 231, 235.

1904. *N. irrorata* Uhler; Kirkaldy, Wien, Ento. Zeit., xxiii, p. 132.

1905. *N. irrorata* Uhler; Bueno, Jl. N. Y. Ento. Soc. xiii, pp. 46, 159; pl. vii, fig. 6.

1907. *N. irrorata* Uhler; Bueno and Brimley, Ento. News, xviii, p. 435. (March to November four newly transformed August 8, N. Car.)

1908. *N. irrorata* Uhler; Bueno, Jl. N. Y. Ento. Soc., xvi, p. 238.

1909. *N. irrorata* Uhler; Kirkaldy and Bueno, Cat. of Am. Aquatic and Semiaquatic Hemiptera, Proc. Ento. Soc. Wash, x, Nos. 3 and 4, p. 198.

1910. *N. irrorata* Uhler, Smith, Cat. Ins. N. J., edn. 3, p. 169.

1913. *N. irrorata* Uhler; Browne, Jl. Exp. Zoöl., xiv, p. 61.

1914. *N. irrorata* Uhler; Parshley, Psyche, xxi, p. 140. (May 22-September 19, Orono & Machias, Maine.)

1914. *N. irrorata* Uhler; Barber, Bull. Am. Mus. Nat. His., xxxiii, p. 499. (From Florida.)

1917. *N. irrorata* Uhler; Hungerford, Ento. News, xxviii, p. 271.

1917. *N. irrorata* Uhler; Parshley, Occasional papers of the Boston Soc. of Nat. His., vii, p. 112. (Me., N. H., Vt., Mass., R. I., Conn.)

1917. *N. irrorata* Uhler; Van Duzee, Cat. of Hemiptera, pp. 450, 451.

1918. *N. irrorata* Uhler; Hungerford, Ento. News, xxix, pp. 242-245; pl. xiv, figs. 1-4; pl. xv, fig. 9. (Illus. ovipositor.)

1919. *N. irrorata* Uhler; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 32, 33, 166, 167, 171, 177, 180-185, 187, 304, 319, 312, 339; pl. xix, figs. 2, 6, 9; pl. xxii, figs. 1-5; pl. xxiii, fig. 9.

1923. *N. irrorata* Uhler; Bueno, Conn. State Geol. and Nat. Hist. Survey Bull., xxxiv, pp. 405, 406, figs. 44, 45; pl. xvi, fig. 7. (April to November.)

1923. *N. irrorata* Uhler; Bueno and Hussey, Bull. Brook. Ento. Soc., xviii, pp. 105, 106.

1925. *N. irrorata* Uhler; Hungerford, Annals Ento Soc. Am., xviii, p. 417.

1925. *N. irrorata* Uhler; Hungerford and Beamer, Ento. News, xxxvi, p. 297. (Kansas Record new.)

1926. *N. irrorata* Uhler; Leonard, Cornell Univ. Agri. Exp. Sta. Memoir 101, p. 138. (March to November.)

1926. *N. irrorata* Uhler; Hungerford, Bull. Brook. Ento. Soc., xxi, p. 194.

1926. *N. irrorata* Uhler; Blatchley, Heteroptera of Eastern N. A., p. 1052.

1928. *N. irrorata* Uhler; Hungerford, Ento. News, xxxix, p. 156. (Georgia.)

1928. *N. irrorata* Uhler; Hungerford, Annals Ento. Soc. Amer., xxi, p. 142.

1929. *N. irrorata* Uhler; Hutchinson, Annals of South African Mus., xxv, pt. 3, p. 363.

Also, referring to this species:

1878. *N. irrorata* Say; Packard, Guide to the Study of Insects, 6th Edn. p. 537. (Without description, a manuscript name of Say used in 1st Edn. 1869.)

Size. Length, 12.9 mm. to 15.5 mm.; width of pronotum, 4.5 mm. to 5 mm.

Shape. The rapid divergence of the lateral margins to the pronotum from the comparatively small head give the appearance of a broad-shouldered back swimmer.

Color. General color is irrorated or mottled brown and blue-black or black. Head, limbs and connexivum of usual color, or a little

darker, often greenish. Pronotum of same color, but darkened on caudal part by the black mesonotum beneath and marked by a median dark brown blotch in front. Scutellum black. Hemelytra irrorated with brown and black or blue-black, the brown usually predominating on the clavus and the black on the corium; the membrane is black. The venter is black. The last abdominal sternite may be testaceous or partly so, and the metaxyphus is usually margined with testaceous.

Structural Characteristics. Anterior outline of the head, as seen from above, somewhat flattened; vertex with anterior width equal to its length; anterior margin of vertex less convex and a little shorter than the frontal margin of an eye; anterior breadth of vertex : synthlipsis :: 3:1; the synthlipsis narrow, only one-third the width of the eye; the inner margins of the eyes diverging widely. Pronotum more than twice the length of the head; lateral margins quite divergent, and nearly straight; anterior angles not embracing the eyes; lateral ledge slightly sigmoid and oblique. Scutellum slightly wider than long. Lobes of membrane about equal. Anterior trochanter of male without hook or tubercle. Mesotrochanters roughly right angulate. The terminal abdominal sternite of female large and constricted near the tip, which is entire; first pair of gonapophyses long. Male genital capsule as shown on Plate XVI.

Location of Type. The type was from "Ipswich, March, Mr. Oakes; Milton, Mass., April 22, 1829." I have seen four specimens in the Boston Society of Natural History Museum (Harris Collection) that may be designated the "cotypes."

Comparative Notes. This species is related to the *Notonecta glauca* Linn. group. The long gonapophyses and the large terminal abdominal sternite of the female and the digitate process on the genital capsule of the male place it clearly with the European species. The only related species of North America is *N. borealis* Bueno and Hussey.

Biological Notes. Bueno tells us that this handsome back swimmer likes the shadows of the bank, overhanging limb, or of aquatic vegetation. I think it does prefer such places, but I have taken it in open ponds. It winters in the deeper ponds and spring-fed, open pools, flying from these quarters to shallower waters for breeding. I have seen them swimming slowly under the ice at the Field Station at Ithaca, N. Y., in early February. Mating has been observed in April in a pool in which they overwintered and from which they soon disappeared, to be found in a meadow pool a quarter of a mile

away. Unlike all other North American species, except *N. borealis* Bueno and Hussey, this species inserts its eggs in the tissues of plants. One female contained 252 ova. The egg stage lasted two or three weeks in late May and first half of June at Ithaca, N. Y., where I made the above observations. After five nymphal instars the adults appeared about the middle of July.

Data on Distribution:

CANADA

QUEBEC: Knowlton, Aug. 12, 1929, G. S. Walley; Aylmer, April 20, 1927, G. S. Walley; Kazubazua, Aug. 18, 1931, G. S. Walley; Fairy Lake, Hull, Sept. 11, 1928, G. S. Walley (Ottawa, Can. Coll.); Montreal, Aug. 1903 (U. S. N. M.).

ONTARIO: Southampton, Sept. 13, 1927, G. S. Walley; Black Rapids, Ottawa, Aug. 25, 1927, G. S. Walley; Arnprior, Sept. 15, 1928, G. S. Walley; Merivale, May 9, 1930, G. S. Walley; Rockcliffe, Ottawa, July 2, 1928. G. H. Fiske; Ventnor, Sept. 2, 1928, J. A. Adams; Vineland Sta., Sept. 11, 1928, W. Putman. (All of above in Ottawa, Canada Collection).

UNITED STATES OF AMERICA

MAINE: Orono, Machias, May 22 to Sept. 19 (Parshley 1914).

MASSACHUSETTS: Mass. (Uhler Coll.); Melrose Heights, Mar. 15, D. H. Clemons.

RHODE ISLAND: R. I. (C. F. Baker Coll.).

CONNECTICUT: Conn. (Uhler Coll.). April 24-Nov. 24. (See Conn. Geol. and Nat. Hist. Surv. Bull. 34).

NEW YORK: Ithaca, every month of year, H. B. Hungerford; New York (Uhler Coll.); Long Island (Uhler Coll.).

NEW JERSEY: Pallisades, Aug. 23, 1903 (U. S. N. M.); Ft. Lee Dist., Oct. 10, 1903 (U. S. N. M.); Madison (Uhler Coll.); N. J. (Uhler Coll.).

PENNSYLVANIA: Philadelphia, 1926, F. Anderson; Penn. (Uhler Coll.); Philadelphia, near Narberth Dec. 19, 1922, W. E. Hoffmann (Minn. Coll.); Hummelstown, April 1, 1917, J. N. Knull.

OHIO: Wellington, July 8, 1890 (Tenn. Coll.); Cincinnati, Dec. 30, 1923, W. E. Hoffmann (Minn. Coll.); Columbus, Sept. 26, 1914, C. J. Drake.

INDIANA: Maxinkuckee; Indiana (Uhler Coll.); South Bend (U. S. N. M.); Kosciusko Co., July, 1932, G. E. Gould.

ILLINOIS: Toledo, Aug. 1891, Harvey; Ill. (Uhler Coll.); Champaign, April, 1907, Hart and Hood; Hilliary, Mar. 23, 1907, Hart and Hood; Dubois, June 20, 1905; Johnson Co., July 20, 1877; St. Francesville, Aug. 23, 1884; Flora, Aug. 22, 1884 (above in Ill. Nat. Hist. Surv. Mus.).

MICHIGAN: Ann Arbor, Sept. 15, 1927, E. Creaser; Bryants Bog, Douglas L., July 17, 1923, Smith's Bog, July 17, 1923, Sedge Pt. Pool, Aug. 16, 1923, Mackinac Island, Aug. 19, 1925, Trout L., Mich. Aug. 25, 1925, Nigger Creek, Mullett Lake, Aug. 4, 1925, Burt Lake, Fontinalis Run, July 7, 1923, Bois Blanc Island, Aug. 14, 1932. All above by H. B. Hungerford.

MINNESOTA: Grand Marais, Aug. 13, 1922, W. E. Hoffmann; Ramsey Co., Nov. 11, 1922, W. E. Hoffmann (Minn. Coll.).

MARYLAND: Crisfield, Baltimore, Frederick (all Uhler Coll.); Plummers Island, April 25, 1913; Laurel, Aug., 1909, F. B. Marshall; Annapolis, Sept. 18, 1932, Paul Oman.

DISTRICT OF COLUMBIA: Rock Creek, Aug. 31, 1906, D. H. Clemons (U. S. N. M.).

VIRGINIA: Chain Bridge, Sept. 3, 1906, D. H. Clemons; Great Falls, May 22, 1906.

TENNESSEE: Monroe Co., July 6, 1890, H. E. Summers (Ill. Nat. Hist. Surv. Mus.).

KENTUCKY: East Cairo, June 7, 1881, S. A. Forbes (Ill. Nat. Hist. Surv. Mus.); Shakertown, July 26, 1932, H. Garman (Garman Coll.).

NORTH CAROLINA: Southern Pines.

SOUTH CAROLINA: Clemson College, Mar. 19, 1927, W. E. Jones; Clemson College, Nov. 28, 1927, D. Dunavan; Jacassee, June 19, 1927; Salem, June 30, 1927, D. Dunavan (all above in S. C. Exp. Sta.); S. C. (Uhler Coll.); Hopkins, Sept., 1920, C. S. Washington (U. S. N. M.).

GEORGIA: Floyd Co., Sept. 1, 1929, Creaser and Becker; Bleckley Co., Sept. 5, 1929, Creaser and Becker; Wrens, July 22, 1930, P. W. Oman; Prattsburg, July 25, 1930, R. H. Beamer; Baker Co., Oct. 23, 1927, C. H. Martin.

FLORIDA: Gainesville, June 9, 1918, Drake; Hilliard, Aug. 19, 1930, R. H. Beamer.

ALABAMA: Prattsville, July 21, 1930, P. W. Oman; Mount Meigs, July 21, 1930, Leonard Tuthill; Ala. (Uhler Coll.).

MISSISSIPPI: Smithville, July 17, 1930, R. H. Beamer; Hamilton, July 15, 1930, P. W. Oman; Scooba, July 17, 1930, P. W. Oman; Iuka, July 14, 1930, P. W. Oman; Crowder, Aug. 30, 1925, H. M. Harris; Charleston, Sept. 7, 1925, H. M. Harris; Agricultural College, Sept. 1, 1925.

LOUISIANA: New Orleans; Baton Rouge, Mar. 9, 1929, R. M. DeCoursey.

TEXAS: Bowie Co., Aug. 16, 1928, R. H. Beamer; Texas (Uhler Coll.).

ARKANSAS: Imboden, B. C. Marshall (U. S. N. M.).

KANSAS: Douglas Co., F. H. Snow; Douglas Co., Rock Pool, Apr. 1, 1933, Carl Cummings; Doniphan Co., Aug. 25, 1924, Linsdale; Cherokee Co., Aug., 1920, Hungerford and Beamer.

ARIZONA: Arizona (Uhler Coll.).

Notonecta borealis Bueno and Hussey, 1923

(Color Plates I, fig. 4, and II, figs. 5 and 10; Plate XVI, fig. 2.)

1923. *N. borealis* Bueno and Hussey, Bull. Brooklyn Ento. Soc., xviii, pp. 104-107, fig. 1 (fig. of female gonapophyses).

1924. *N. borealis* Bueno and Hussey; Hungerford, Kansas Univ. Sci. Bull., xiv, p. 426 (says fig. labeled *N. lutea* on plate xxxi, Kans. Univ. Sci. Bull. xi, is *N. borealis* B. & H.)

1926. *N. borealis* Bueno and Hussey; Blatchley, Heteroptera. . . . p. 1053.

1926. *N. borealis* Bueno and Hussey; Hungerford, Bull. Brooklyn Ento. Soc., xxi, p. 194 (Abundant in Michigan).

1928. *N. borealis* Bueno and Hussey; Hungerford, Annals Ento. Soc. Amer., xxi, p. 142.

1928. *N. borealis* Bueno and Hussey; Hungerford, Can. Ento., lx, p. 76. (Describes dark-colored forms.)

1929. *N. borealis* Bueno and Hussey; Hutchinson, Annals of South African Museum, xxv, pt. 3, p. 363.

1930. *N. borealis* Bueno and Hussey; Walley, Can. Ento., vol. lxii, No. 4, p. 77.

Also referring to this species:

1897. *N. insulata* Kirkaldy, Trans. Ento. Soc. London for 1897, p. 405. (Specimen in Signoret's Coll. labeled *N. rugosa.*)

1904. *N. lutea* Bueno, Ento. News, xv, p. 220.

1905. *N. lutea* Bueno, Jl. N. Y. Ento. Soc., xiii, p. 160.

1908. *N. ? lutea* Kirkaldy and Bueno, Proc. Ento. Soc. Wash., x, p. 198. (Says American species is not Müller's.)

1917. *N. lutea* Van Duzee, Cat. Hem. Amer. North of Mexico, p. 450.

1918. *N. lutea* Hungerford, Ento. News, xxix, p. 244, pl. xv, fig. 1 (fig. of ovipositor).

1919. *N. lutea* Hungerford, Kans. Univ. Sci. Bull., xi, p. 331.

Size. Length, 12.4 mm. to 14.2 mm.; width of pronotum, 4.3 mm. to 5.1 mm.

Shape. Plump, deep bodied, with the abdomen broader than the pronotum at the humeral angles.

Color. General color luteous, usually with a dark streak following the costal margin from the base of the hemelytra; membrane pale. Scutellum pale yellow. Pronotum, head and limbs ivory white or the last darker or streaked with brown; sometimes face and limbs more or less greenish. Venter dark. In some specimens the brown streak nearly covers the clavus, and in rare cases specimens have been encountered that have a black scutellum and hemelytra as dark as in *N. irrorata* Uhler. In such cases of melanchroism, however, the posterior lobe of the membrane remains pale.

Structural Characteristics. Anterior outline of head, viewed from above, somewhat flattened, but vertex produced beyond the eyes; vertex at least a fifth broader in front than its length; anterior margin of vertex less convex and plainly longer than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 2.3:1. Pronotum slightly more than twice as long as the head; lateral margins divergent, slightly concave; anterior angles not embracing the eyes; lateral ledge sigmoid and oblique and shorter than the length of the eye below it. Scutellum small, slightly shorter than the pronotum. Posterior lobe of membrane shorter than the anterior lobe. Anterior trochanters of the male without hook or tubercle; mesotrochanters rounded. The terminal abdominal sternite of the female large and constricted near the tip, which is entire. First pair of gonapophyses long. Male genital capsule as shown on Plate XVI.

Location of Type. Type and paratypes in collection of J. R. de la Torre-Buneo; paratypes in collections of R. F. Hussey, H. B. Hungerford, H. M. Parshley, W. E. Hoffmann, and the Museum of Zoölogy, University of Michigan.

Comparative Notes. This species is related to *N. lutea* Müller of northern Europe from which it differs in a number of respects. Besides the differences in genitalia in both sexes, the *N. lutea* Müller

has a hook on the anterior trochanter of the male. Both the head and mesofemoral spine of *N. borealis* B. & H. are relatively smaller than in the old world form.

Biological Notes. This species deposits its eggs in the tissues of aquatic plants. The eggs may be completely covered or be partially exposed. The life history of this species should be studied. Miss Lucile Rice made some observations (unpublished) on this species at the Biological Station of the University of Michigan on Douglas Lake during the summer of 1927. She found no adults before June 29th, at which time she took two, and observed many last instar nymphs. Seven of these nymphs transformed in the laboratory within the next twenty-four hours. By July 6th there were many adults in the pool. One of the adults brought in June 29th deposited an egg on July 9th. Egg laying continued till August 11th. However, none of the eggs, either from laboratory or field, showed any signs of developing during the summer. Miss Rice therefore took them to Tennessee, and some of them deposited July 22d hatched in her laboratory on December 15th.

From the collecting records which I have made about Douglas Lake, during a period of ten years, and from Miss Rice's observation, it appears that this northern species winters in the egg state.

Data on Distribution:

CANADA

QUEBEC: East Coast James Bay, Sept., 1920, F. Johansen; Natashquan, Que., Aug. 8, 10, 11, 1929, W. J. Brown (Ottawa, Can.).

BRITISH COLUMBIA: Bearfoot Mts., Sept. 17, 1903 (U. S. N. M.).

UNITED STATES OF AMERICA

MICHIGAN: Cheboygan Co., Aug. 29, 1918; Douglas L., July 4, 1926, C. H. Martin; Douglas L., July 29, 1926, H. B. Hungerford; Douglas L. (Sedge Pool), 1925 and July 6, 1923, H. B. Hungerford; Douglas L. (Bryants Bog), July 17, 1925, H. B. Hungerford; Mackinac Island, Michigan, Aug. 19, 1925, and Aug. 4, 1929, H. B. Hungerford.

MINNESOTA: Lake Co., Stony R. Camp No. 9, Aug. 16, 1922, H. B. Hungerford, H. H. Knight, W. E. Hoffmann; Hibbings, Aug. 18, 1922, H. B. Hungerford.

Notonecta melaena Kirkaldy, 1897

(Color Plate III, fig. 7; Plate XIII, fig. 11)

1897. *N. shooterii* var. *melaena* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 406.
1904. *N. shooterii* var. *melaena* Kirkaldy, Wien. Ento. Zeit., XXIII, p. 132.
1905. *N. shooterii* var. *melaena* Kirkaldy; Bueno, Jl. N. Y. Ento. Soc., XIII, p. 161.

Referring to this species, also:

1897. *N. shooterii* var. *tearca* Kirkaldy, Trans. Ento. Soc. London, 1897, p. 407.
1925. *N. distincta* Hungerford, Can. Ento., LVII, p. 241, pl. VI, fig. 4.
1928. *N. distincta* Hungerford, Annals Ento. Soc. Am., XXI, pl. IX, fig. 3.

Size. Length, 10.8 mm. to 11.7 mm.; width of pronotum, 4 mm. to 4.3 mm.

Color. A bichromatic species, the luteous forms having a tinge of orange, the pigmented forms with black scutellum and hemelytra varying from light brown to nearly black; a light-brown streak may be present along costal margin and above the claval suture; base of membrane black and tip white. Propleura mostly pale. Pro- and mesosternum dark. Abdominal venter with black maculations.

Structural Characteristics. Head less than one-half length of pronotum; vertex shorter than its anterior width as seen from above; anterior margin of vertex less convex than frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 11:7; the synthlipsis broad, slightly more than half the rear margin of an eye; inner margins of eyes concave. Pronotum steeply declivant; lateral margins of pronotum nearly straight and diverging at an angle of from 44 to 50 degrees, in the dark form slightly convex and diverging less markedly, the angle being about 42 degrees; anterolateral angle embracing the eye, more in the luteous forms than in the pigmented forms, some of which show angles but slightly acute; lateral ledge a little broader in the luteous forms and shorter than the rear margin of the eye beneath, as long as rear margin of the eye in the pigmented forms; lateral ledge faintly sigmoid, the anterior end curved downward and posterior end turned upward. Posterior lobe of membrane much reduced in luteous forms and slightly shorter in dark forms. Anterior trochanter of male with basal tubercle and stout hook characteristic of the *N. shooteri* Uhler group. Mesotrochanters rounded. Penultimate abdominal sternite of female broadly triangular, broadly notched at tip and overlapping base of following sternite, which is not notched at tip. Female gonapophyses short. Male genital capsule as shown on Plate XIII, fig. 11.

Location of Type. Kirkaldy named this as a variety of *N. shooterii* Uhler, from Mexico (Noualhier coll.). I have seen this specimen, a male, in the Paris Museum. My *N. distincta* is the same species. I have seen the pale specimens mentioned by Kirkaldy as having developed posterior lobes to the membranes and for which he proposed the varietal name *tearca*. He says: "This form I have seen only from Mexico (in Stockholm Mus. and in the Paris Mus., where it was labeled "*americana*" by Fallou)." The Paris specimens are labeled "Mexique, Coll. G. Fallou 259-95." The male has the membrane lobes subequal, but the female has them unequal like the

Colombian specimen he labeled *"ochrothoe."* As far as I can determine the luteous male with the normal posterior lobe of the membrane is an unpigmented specimen of the dark form of *N. melaena* Kirkaldy.

Comparative Notes. The pigmented forms have been confused until recently with *N. distinctoidea* Hungerford, being about the same size and color. The presence of the large hook on the anterior trochanter of the male and the penultimate abdominal sternite of female notched, separate this species from *N. distinctoidea* Hungerford.

Notes on Distribution. Described from Mexico. Paris Museum has a series of dark forms labeled "Etat Jalisco, L. Diguet 1903." I have specimens labeled: "10 miles N. E. Leon Quanajuato, Mex. Aug. 17, 1932, Hobart Smith"; my *N. distincta* type is labeled "Comondú, Lower Calif. Chas. D. Haines, March, 1889." The two specimens I recognize as the luteous form of this species are labeled "Las Parras, Baja, Calif., W. M. Mann."

*Notonecta ochrothoe** Kirkaldy, 1897

1897. *N. shooterii* var. *ochrothoe* Kirkaldy, Trans. Ento. Soc. London for 1897, p. 407.
1905. *N. shooterii* var. *ochrothoe* Kirkaldy; Bueno, Jl. N. Y. Ento. Soc., XIII, p. 161.

Size. Length, 10.8 mm. to 11.4 mm.; width of pronotum, 4 mm. to 4.4 mm.

Color. Only the luteous form known to me, and this is pale luteous.

Structural Characteristics. Anterior outline of head, viewed from above, convex; vertex usually shorter than its anterior width; margin of vertex less convex than margin of the eye; anterior breadth of vertex : synthlipsis :: 3:2. Pronotum not markedly declivant; pronotum more than twice length of head; lateral margins slightly divergent and nearly straight; anterolateral angles acute and embracing the eyes; lateral ledge, as seen from the side, nearly straight, about as long as rear margin of the eye beneath. Scutellum shorter than pronotum. Posterior lobe of membrane reduced. Anterior trochanter of male with stout hook and tuberculate projection on basal angle. Mesotrochanter rounded. The penultimate abdominal sternite of female broadly triangular, tip incised and projecting upon the base of the last sternite, which is not notched at tip.

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* Kirkaldy, 1904, in his Über Notonectiden, Wien. Ent. Ziet., XXIII, and in his Catalogue Proc. Ent. Soc. Wash., X, appears to have dropped this variety. Nevertheless I find a male in the Paris Museum from "Colombie" labeled this species by Kirkaldy, and since it is not *N. shooterii* Uhler, I make it the type and raise his variety to specific rank.

Female gonapophyses short. Male genital capsule shaped much like *N. melaena* Kirk. but with a thickened protuberance on keel.

Location of Type. In Paris Museum.

Comparative Notes. Differs from luteous form of *N. melaena* Kirkaldy by less declivant pronotum and by the thickened protuberance on the keel of the male genital capsule.

Data on Distribution. Colombia, S. A., and the following: "San Cristobel M. F. 3-7-1929"; San Diego Co., Calif., Doway Val., 4-9, 1930, C. and D. Martin.

Notonecta repanda new species

(Text figure 7)

Size. Length, 11.7 mm. to 13.8 mm.; width of pronotum, 4 mm. to 4.8 mm.

Color. Color markings as in *N. shooteri* Uhler.

Structural Characteristics. Anterior outline of head, viewed from above, less convex than in *N. shooteri* Uhler; vertex shorter than its anterior width; margin of vertex usually less convex than margin of the eye; anterior breadth of vertex : synthlipsis : : 3:2. Pronotum less than twice the length of the head; lateral margins slightly divergent and straight to slightly convex, more divergent, of course, in the dark forms; anterior angles acute and closely embracing the eyes; lateral ledge, as seen from the side, nearly straight throughout and as long or longer than the rear margin of the eye below it; anterior end of lateral ledge of pronotum broadly flattened, the ledge plainly wider beneath than the diameter of the second antennal segment. Scutellum short as in *N. shooteri* Uhler. The color forms as in *N. shooteri* Uhler. Trochanters the same. The penultimate abdominal sternite of female broadly triangular, the apex broader than in Uhler's species, but projecting upon last sternite, which is not notched at tip. Female gonapophyses short. Male capsule not elongate but compact much as in *N. melaena*.

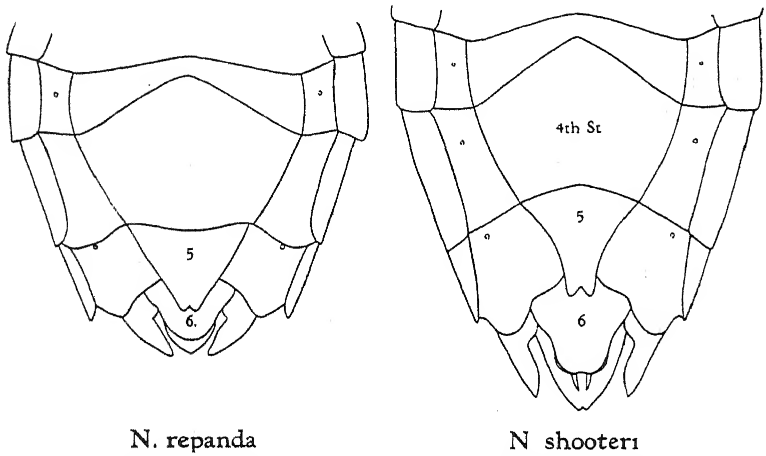
Location of Type. In the Francis Huntington Snow Entomological Museum of the University of Kansas. Described from 35 specimens labeled: "Cochise Co., Arizona, July 29, 1927, P. A. Readio, R. H. Beamer, L. D. Anderson."

Comparative Notes. This species has the appearance of *N. shooteri* Uhler, but the lateral ledge of the pronotum is more explanate, the genital capsules of males different and the penultimate abdominal sternite of female broader in the portion that overlaps the last segment.

Data on Distribution:

ARIZONA: Cochise Co., July 29, 1927 (type series); Baboquivari Mts., July 18, 1932, R. H. Beamer; Douglas, Aug., San Bernardino Ranch, 3,750 feet, F. H. Snow.

MEXICO: D. F. Texoco Sea, Jan. 31, 1926, A. Dampf.; Mexico D. F., Apr. 22, 1910; D. Fedrl. L. Conradt (U. S. N. M.); Xochimilco Lake, near Mexico City, June 2, 1926, A. Dampf.



TEXT FIGURE 7. *Notonecta repanda* Hungerford and *Notonecta shooteri* Uhler. Underside of abdomen of females. (Subgenus Bichromonecta.)

Notonecta shooteri Uhler, 1894

(Color Plate I, fig. 6; Plate XIII, fig. 8, Text fig. 7)

1894. *N. shooterii* Uhler; Proc. Calif. Acad. Sci. (2), iv, p. 292.
1897. *N. shooterii* Uhler; Kirkaldy, Trans. Ento. Soc. London for 1897, p. 406 (in part).
1901. *N. shooterii* Uhler; Champion, Biol. Centr. Amer., Hem.-Het. II, p. 370 (in part).
1904. *N. shooterii* Uhler; Kirkaldy, Wien. Ento. Zeit., xxiii, pp. 94 and 132.
1905. *N. shooterii* Uhler; Bueno, Jl. N. Y. Ento. Soc., xiii, p. 161.
1909. *N. shooterii* Uhler; Kirkaldy & Bueno, Proc. Ent. Soc. Wash., x, p. 199.
1916. *N. shooteri* Uhler; Browne, Jl. Morph., xxvii, p. 129 (Cytology).
1917. *N. shooterii* Uhler; Van Duzee, Catalog Hemipt., p. 453 (in part).
1918. *N. shooterii* Uhler; Hungerford, Ento. News, xxix, p. 245, pt. xv, fig. 8. (Ovipositor.)
1919. *N. shooterii* Uhler; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 168, 172, 181, 312, 331; pl. xxiii, fig. 8, pl. xxxi, fig. 5.
1922. *N. shooterii* Uhler; Hungerford, Kans. Univ. Sci. Bull., xiv, p. 426.
1923. *N. shooterii* Uhler; Bueno & Hussey, Bull. Brookl. Ent. Soc., xviii, p. 106.
1924. *N. shooterii* Uhler; Hale, Proc. Lin. Soc. N. S. Wales, xlix, pt. 4, p. 462.
1928. *N. shooterii* Uhler; Hungerford, Annals Ento. Soc. Amer., xxi, p. 143; pl. ix, fig. 5. (Anterior trochanter of male.)
1928. *N. shooterii* Uhler; Hungerford, Can. Ento., lx, p. 76.
1929. *N. shooterii* Uhler; Hutchinson, Annals S. Afr. Mus., xxv, pt. iii, p. 364.

Size. Length, 11.7 mm. to 13.5 mm.; width of pronotum, 4.4 mm. to 4.8 mm.

Color. A bichromatic species. One form pale luteous with or

without a submarginal stripe and one or two elongate triangular brown spots on corium. The other form dark, with black scutellum and brown hemelytra, which are streaked and spotted with pale luteous, the pale markings being a broad streak on clavus, a transverse irregular spot at end of basal third of corium, a spot at distal end of corium and another on anterior lobe of membrane. The posterior lobe of membrane may be pale to nearly black. The abdominal venter luteous with brown maculations in both color phases. Face, limbs and connexivum may be yellowish or suffused with green.

Structural Characteristics. Anterior outline of head, viewed from above, convex; vertex usually longer or subequal to its anterior width; margin of vertex more convex than margin of the eye; anterior breadth of vertex : synthlipsis :: 9.3:5.5. Inner margins of eyes slightly concave. Pronotum usually less than twice the length of the head; lateral margins slightly divergent and straight to slightly convex; anterolateral angles acute and closely embracing the eyes; lateral ledge, as seen from the side, straight in front, undulate behind, shorter than the rear margin of the eye below it, and nearly horizontal. Scutellum short, about as long as pronotum and shorter than ridges of hemelytral commissure. Anterior lobe of membrane much longer and more developed than the posterior lobe in luteous phase and plainly longer in the dark phase. The luteous forms, besides the reduced posterior lobe of hemelytra, have the flight wings reduced, and this is accompanied by a reduction in the prominence of the humeri and in the size of the scutellum. The reduced humeri cause the lateral margins of the pronotum to appear more nearly parallel. Anterior trochanters of the males with broad, stout hook in usual position and in addition a tuberculate projection on basal angle (see plate IX, fig. 4). Mesotrochanter rounded. The penultimate abdominal sternite of female elongate triangular, the sides converging caudally, tip incised and projecting upon the base of last sternite, which is not notched at tip. Female gonapophyses (first pair) short. Male genital capsule as shown on Plate XIII.

Location of Type. In the Uhler collection at the U. S. N. M., Washington, D. C. The type series was found near San Diego, California, on October 19, by Mr. Shooter, for whom Doctor Uhler named the species. The spelling of the name might have been *N. shooteri.*

Comparative Notes. This species is typical of a group that have the large, stout hook on anterior trochanters of the males and fe-

males, with the penultimate sternite elongate triangular, thus intermediate between the *N. mexicana* A. & S. series and the *N. undulata* Say group. The males readily recognized by the elongate portion of the capsule behind the keel protuberence.

Data on Distribution. The group as a whole ranges from California to Colombia, S. A., but the species *N. shooteri* Uhler appears to be restricted to California. I have the following records:

CALIFORNIA: Marin Co., Aug. 3, 1929, L. D. Anderson; Winters, Aug. 6, 1929, L. D. Anderson; Campo, Laguna Mts., Aug. 25, 1932, H. W. Capps; Fresno, June 20, 1926, C. J. Drake; Laguna Beach, C. T. Dodds; Los Angeles (Uhler Coll.); San Diego, Oct. 19, Mr. Shooter (Uhler Coll.).

"VITI-INS": Distant coll. 1911-383 (British Mus.).

Notonecta uhleri Kirkaldy, 1897

(Color Plate III, fig. 9; Plate XIII, fig. 10)

1897. *N. uhleri* Kirkaldy, Annals & Mag. Nat. Hist., ser. 6, xx, p. 58.

1897. *N. uhleri* Kirkaldy, Trans. Ento Soc. London, 1897, p. 415.

1902. *N. uhleri* Kirkaldy; Bueno, Jl. N. Y. Ento. Soc., x, pp. 231, 235.

1904. *N. uhleri* Kirkaldy, Wien. Ento. Zeit, xxiii, p. 132.

1905. *N. uhleri* Kirkaldy; Bueno, Jl. N. Y. Ento. Soc., xiii, pp. 46 and 157, pl. vii, fig. 4.

1906. *N. uhleri* Kirkaldy; Bueno and Brimley, Ento. News, xviii, p. 436.

1909. *N. uhleri* Kirkaldy and Bueno, Proc. Ento. Soc. Washington, x, No. 3-4, p. 199. (Cat. of Am. Aquatic & Semiaquatic Hemiptera.)

1910. *N. uhleri* Kirkaldy; Smith, Cat. Ins. N. J., edn. 3, p. 169.

1914. *N. uhleri* Kirkaldy; Barber, Bull. Am. Mus. Nat. Hist., xxxiii, p. 499.

1917. *N. uhleri* Kirkaldy; Parshley, Occasional Papers of the Boston Society of Natural History, vii, p. 112.

1917. *N. uhleri* Kirkaldy; Van Duzee, Catalog of Hemiptera, p. 451.

1918. *N. uhleri* Kirkaldy; Hungerford, Ento. News, xxix, p. 245, Pl. xv, fig. 10.

1919. *N. uhleri* Kirkaldy; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 167, 170, 180, 181, 312, 331; Pl. xxiii, fig. 10.

1923. *N. uhleri* Kirkaldy; Bueno, Conn. State Geol. & Nat. Hist. Survey Bull. No. 34, p. 405.

1923. *N. uhleri* Kirkaldy; Hungerford, Kansas Univ. Sci. Bull., xiv, p. 426. (Mention only).

1926. *N. uhleri* Kirkaldy; Blatchley, Heteroptera of Eastern North America, p. 1055.

1926. *N. uhleri* Kirkaldy; Leonard, Cornell Univ. Agri. Exp. Sta. Memoir 101, p. 138, (Apr. to Nov.)

1928. *N. uhleri* Kirkaldy: Hungerford, Ento. News, xxxix, p. 156.

Size. Length, 10 mm. to 12 mm.; width across pronotum, 3.3 mm. to 4 mm. The males usually smaller than the females.

Shape. The males at least are slender.

Color. Orange to brick red and black. Anterior half of pronotum, head, limbs and underside of connexivum of usual color or a little darker and sometimes greenish; a dark linear longitudinal band usually present on pronotum behind the caudolateral margin of the eye. Scutellum black. Hemelytra orange to brick red; corium crossed by broad, irregular black band extending from near tip of

clavus to costal margin. Posterior lobe, at least of membrane, dark, and both lobes crossed by black or nearly black band that often covers the lobes to their tips and sometimes darkens entire membrane. The hemelytra usually clothed with silvery hairs that are more pronounced on the corium; a few such hairs may also be seen on scutellum. The venter is dark.

Structural Characteristics. Anterior outline of the head, as seen from above, slightly convex; vertex longer than its anterior width and "shaped like an inverted wine-decanter"; anterior margin of vertex shorter than the frontal margin of an eye; the anterior breadth of vertex : synthlipsis :: 6 or 8:1; the eyes at synthlipsis often nearly contiguous and their inner margins curved. Head shorter than length of pronotum. Lateral margins of pronotum strongly divergent and moderately concave; anterior angles normal; lateral ledge, as seen from the side, curved (convex above), oblique and plainly shorter than the rear margin of the eye below it. The scutellum plainly longer than the pronotum and also longer than the ridge of the hemelytral suture. Lobes of membrane subequal, the anterior lobe sometimes slightly longer. Anterior trochanter of the male with a slight tubercle in place of a hook. Mesotrochanter right-angulate or slightly produced. Terminal abdominal sternite of female carinate and slightly notched at tip; the first pair of gonapophyses short. The male genital capsule as shown on Plate XIII, fig. 10.

Location of Type. In the P. R. Uhler collection at the U. S. N. Museum.

Comparative Notes. The small size, the reddish and black color and the very narrow synthlipsis readily distinguish this species.

Data on Distribution. A Uhler specimen is labeled "Stony Run, Pa." "Among grass in water." In the Paris Museum I found a specimen compared with type by Kirkaldy labeled "Mus. Paris, Neue Orleans, Coll. Guérin Menev. ex. coll. A. Salle, 1897." The British Museum has specimens from Mass. The Uhler collection from Florida and Massachusetts. Bueno reports it from New York, Washington, D. C., New Jersey and Louisiana. Doctor Drake took it at Gainesville, Florida. Doctor Blatchley adds: Maryland, North Carolina and southern Illinois. There are specimens in the University of Kansas collection labeled as follows: "Boardman, N. C., Sept. 21, 1915, R. W. Leiby"; "Raleigh, N. C., Oct. 16, 1905, C. S. Brimley"; "Florence, S. C., July 2, 1930, D. Dunavan (Clemson College Coll.);" "Putnam Co., N. Y."; "Leland, Miss., 9-14-21";

"Baker Co., Ga., Oct. 23, 1927, C. H. Martin"; "Prattsburg, Ga., 7-25-1930, R. H. Beamer"; "Hilliard, Fla., 8-31-30, Paul W. Oman"; "Norfolk, Va., 8-15-28, G. E. Gould;" also "Oct. 1, 1932, L. D. Anderson; Annapolis, Md., Sept. 18, 1932, Paul Oman."

Thus *N. uhleri* Kirkaldy has been taken in the following states: Mass., New Jersey, Pa., N. Y., Md., Va., Dist. of Columbia, Ill., N. Carolina, La., Ga., Fla., Miss. The range, so far as we know it, extends, therefore, from Massachusetts south to Florida and westward to the Mississippi river.

Notonecta raleighi Bueno, 1907

(Color Plate I, fig. 7; Plate XIII, fig. 6)

1907. *N. raleighi* Bueno, Can. Ento. xxxix, p. 225.

1907. *N. raleighi* Bueno and Brimley, Ento. News, xviii, p. 436. (Feb. to Nov. in N. Carolina.)

1909. *N. raleighi* Bueno; Kirkaldy & Bueno, Proc. Ento. Soc. Wash., x, p. 199.

1910. *N. raleighi* Bueno; Smith, Catalog Ins. N. J., edn. 3, p. 169.

1917. *N. raleighi* Bueno; Van Duzee, Catalog Hemip., p. 452.

1918. *N. raleighi* Bueno; Hungerford, Ento. News, xxix, p. 245, pl. xv, fig. 2. (Fig. of ovipositor.)

1919. *N. raleighi* Bueno; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 167, 169, 181, 239, 331; pl. xxiii, fig. 2.

1923. *N. raleighi* Bueno; Conn. St. Geol. & Nat. Hist. Survey Bull. No. xxxiv, pp. 404-405.

1925. *N. raleighi* Bueno; Hungerford & Beamer, Ento. News, xxxvi, p. 297.

1926. *N. raleighi* Bueno; Leonard, Cornell Univ. Agri. Exp. Sta. Memoir 101, p. 139. (March, White Plains, N. Y. det. Bueno.)

1926. *N. raleighi* Bueno; Blatchley, Heteroptera . . . p. 1055.

1930. *N. raleighi* Bueno; Hungerford, Bull. Brookl. Ento. Soc., xxv, p. 140.

Referring to this species, also:

Probably some specimens prior to 1907 were included under *N. variabilis* Fieber in error.

Size. Length, 8 mm. to 8.9 mm.; width of pronotum, 2.5 mm. to 2.9 mm.

Color. A pale species that may be pale yellowish throughout or with scutellum black save for lateral margins and hemelytra more or less smudged with black. Bueno says: "Scutellum ranges from pure light yellowish to black, disk margined with smoky orange-yellow on hemelytral margins. Hemelytra ranging from white with vague beginnings of the corial fasciæ and black humeri with white membrane, through all intergrades to a form with a blackish stripe along the anterior margin of the corium; black margins to the clavus along the scutellar edges; a black streak along the corium near to and parallel to the claval suture; black corial fasciæ merging into the black membrane which shade off into smoky and then white at apex. One of the types is the most pronouncedly melanic speci-

men of the species in a series of sixty or so specimens. In this the extreme of scutellar darkness with orange-red edges obtains. The external edges of the clavus are broadly black, shading into smoky to the corial suture; the dark band on the corium parallel to this suture is broad; the humerus has a black streak running into the corium, which is dark luteous, except for the black fasciæ which coalesce with the black membrane, which in turn lightens to smoky at the apex."

Structural Characteristics. Our smallest North American species. Anterior outline of head somewhat rounded, vertex and eyes in nearly an even curve: vertex slightly longer than its anterior width; anterior margin of vertex about equal to the frontal margin of the eye. Anterior breadth of vertex : synthlipsis :: 5:1, often less. Synthlipsis usually less than one-fourth the width of the eye. Pronotum two- to four-tenths longer than the head, lateral margins straight, divergent, anterior angles normal to slightly embracing the eyes, lateral ledge a little bowed and oblique as seen from the side. Membrane lobes subequal. Anterior trochanters of male with minute hook; mesotrochanter right angulate to acutely angulate (one specimen with rounded trochanter). Terminal abdominal sternite of female incised at tip, male genital capsule as shown on Plate XIII.

Location of Types. Described from sixteen specimens from Raleigh, N. C. Types: Collections U. S. National Museum, American Museum of Natural History, C. S. Brimley and Bueno.

Comparative Notes. Although this species was described as having "vertex more than six times as wide as synthlipsis," I have seen no specimens with such a narrow synthlipsis. Many specimens from the type locality, some determined by Bueno, have come under my observations. In my "Biology of Aquatic and Semiaquatic Hemiptera" I separated this species from *N. variabilis* (now *N. lunata*) as follows:

"Vertex 3 times synthlipsis .... *N. variabilis.*
Vertex 6 times synthlipsis .... *N. raleighi.*"

I took these statements from the literature, and Doctor Blatchley, in his "Heteroptera,"[6] used the same statements. The problem of separating these species is by no means so simple. After studying much material involving an examination of all specific characters known to me I must confess my failure to find definite distinctive characters. All gradations appear to occur. The male genitalia are not clearly distinguishable. Typical specimens of *N. raleighi* Bueno are smaller and synthlipsis is narrower than in the form we

know as *N. lunata* Hungerford. The latter appear to be the common form in New York state and in Michigan, while the former is more southern in distribution.

Notonecta lunata Hungerford, 1926

(Color Plate I, fig. 5; Plate XIII, fig. 5)

1926. *N. lunata* Hungerford, Psyche, xxxiii, p. 12. (new name for *N. variabilis maculata* Fieb.).
1926. *N. lunata* Hungerford, Bull. Brooklyn Ento. Soc., xxi, p. 195.
1928. *N. lunata* Hungerford, Annals Ento. Soc. Amer., xxi, p. 143.
1930. *N. lunata* Hungerford, Bull. Brooklyn Ento. Soc., xxv, p. 140.

Referring to this species, also:

1851. *N. variabilis* var. *maculata* Fieber, Rhynchotographieen, p. 477.
1851. *N. variabilis* var. *maculata* Fieber, Rhynchotographien, p. 53 (Van Duzee).
1878. *N. undulata* Uhler, Proc. Boston Soc. Nat. Hist., xix, p. 442 (var. Σ).
1885. *N. undulata* Uhler, Stand. Nat. Hist., II, p. 252 (in part).
1897. *N. variabilis* Kirkaldy, Trans. Ento. Soc. London for 1897, p. 414 (the N. A. forms).
1899. *N. americana* Ashmead, Smiths Ins. N. J., p. 144 (Bueno).
1901. *N. variabilis* Champion, Biol. Centr. Amer. Hem.-Het., II, p. 370.
1902. *N. variabilis*, Bueno, Jl. N. Y. Ento. Soc., x, pp. 231 and 234.
1904. *N. variabilis* Kirkaldy, Wien. Ento. Zeit., xxiii, p. 95 (in part).
1905. *N. variabilis* Bueno, Jl. N. Y. Ento. Soc., xiii, pp. 45 and 155.
1908. *N. variabilis* Bueno, Jl. N. Y. Ento. Soc., xvi, p. 238.
1909. *N. variabilis* Kirkaldy and Bueno, Proc., Ento. Soc. Wash., x, p. 199 (in part).
1910. *N. variabilis* Smith, Catalog Ins. N. J., edn. 3, p. 169.
1910. *N. variabilis* Bueno and Brimley, Ento. News, xviii, p. 435.
1912. *N. variabilis* Bueno, Can. Ento., xliv, p. 213.
1914. *N. variabilis* Parshley, Psyche, xxi, p. 140. (Apr. to Sept. in Maine.)
1914. *N. variabilis* Barber, Bull. Am. Mus. Nat. Hist., xxxiii, p. 499 (Florida).
1917. *N. variabilis* Hungerford, Ento. News, xxviii, p. 267.
1917. *N. variabilis*, Parshley, Occ. Papers of Boston Soc. Nat. Hist., vii, p. 112.
1917. *N. variabilis* Van Duzee, Catalog Hem., p. 451.
1918. *N. variabilis* Hungerford, Ento. News, xxix, pp. 242, 243, 245; Pl. xv, fig. 4 (Ovipositor).
1919. *N. variabilis* Hungerford. Kans. Univ. Sci. Bull., xi, pp. 22, 167, 169, 170, 180, 181, 186, 187, 193; Pl. viii fig. 4; Pl. xix, figs. 1, 5, 8, 11, 13; Pl. xxiii, fig. 4.
1919. *N. variabilis* Hungerford, Kans. Univ. Sci. Bull., xi, pp. 331, 332; Pl. xxxi, fig. II (male genital capsule).
1923. *N. variabilis* Bueno, Conn. St. Geol. and Nat. Hist. Survey Bull., No. 34, pp. 404, 405; Pl. xvi, fig. 5. (May to Oct.)
1925 *N. variabilis*, Hungerford, and Beamer, Ento. News, xxxvi, pp. 264 and 297.
1926. *N. variabilis* Leonard, Cornell Univ. Agri. Exp. Sta., Memoir 101, p. 139. (Mar. to Nov.)

Size. Length, 8.5 mm., to 10.7 mm.; width of pronotum, 2.8 mm. to 3.5 mm.

Color. A pale species from nearly white to yellowish with scutellum nearly always yellowish. Head, pronotum and limbs often greenish. Hemelytra only occasionally with a smoky band in corium and a spot near tip of corium.

Structural Characteristics. Difficult to distinguish from *N. raleighi* Bueno. Vertex slightly shorter than anterior width; anterior margin

of vertex slightly longer than frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 3:1; synthlipsis usually about a third the width of an eye. Pronotum four- to six-tenths longer than the head; lateral margins nearly straight, divergent; anterior angles normal, lateral ledge nearly straight and oblique as seen from the side. Membrane lobes about equal, anterior lobe may be trifle longer. Anterior trochanters of male with the usual small hook, mesotrachanters acutely angulate, terminal abdominal sternite of female incised at tip. Male genital capsule as in *N. raleighi* Bueno. (See plate XIII, fig. 5.)

Location of Type. *N. lunata* was a name proposed to replace the name *N. variabilis* var. *maculata* Fieber, a name previously used. I have not been able to find any specimens from Baltimore in the Berlin Museum that might have been studied by Fieber. Whether Fieber had *N. raleighi* Bueno or *N. lunata* Hungerford is impossible to determine. By general consent both were called *N. variabilis* until Bueno described *N. raleighi,* leaving the larger forms to be called *N. variabilis.* As I have pointed out, *N. variabilis* Fieb. must be a South American form.

I have labeled a series of insects from Ithaca, N. Y., as typical of *N. lunata* Hungerford. They are in the Francis Huntington Snow collection at the University of Kansas.

Data on Distribution. The following records have been furnished by G. S. Walley, who has kindly determined the specimens in the Ottawa collection and given me the data:

CANADA

NEW BURNSWICK: Ludlow, July 7, 1928; W. J. Brown.

QUEBEC: Fairy Lake, Hull, May 3-17, 1927, G. S. Walley; May 16, 1928, W. J. Brown; Sept. 11, 1928, G. S. Walley. Knowlton, Aug. 12, 1929, G. S. Walley. Missisquoi Bay, July 11, 1927, G. S. Walley. Brome Lake, July 8, 1927, G. S. Walley.

ONTARIO: Black Rapids, Ottawa, Apr. 27, May 11, 1927, G. S. Walley. Jock River, Ottawa, Apr. 20, May 21, Aug. 25, 1927, G. S. Walley. Britannia, Aug. 21, 1927, W. J. Brown. Ventnor, Aug. 5, Sept. 1, 1928, J. A. Adams. Chesley Lake, Aug. 23, 1928, G. S. Walley. Arran Lake, June 20, 1921, G. S. Walley. Southampton, Sept. 13, 1927, G. S. Walley. Dundas, May 31, 1931, G. S. Walley. Pt. Pelee, June 3, 6, 1929, G. S. Walley and L. J. Milne. Leamington, July 6, 1931, G. S. Walley.

Notonecta unifasciata unifasciata Guérin, 1857

(Color Plate I, fig, 12; Plate XIV, figs. 1, 2, 3.)

1857. *N. unifasciata* Guérin-Meneville, Le Moniteur Universel, 26 Nov., 1857, Numéro 330, p. 1298.
1857. *N. unifasciata* Guérin-Meneville, Revue et Magasin de Zoölogie, 2d ser., Tom. ix, pp. 522-527.
1858. *N. unifasciata* Guérin-Meneville, L'Illustration, Tom. xxxii, p. 47, Juillet 17,1858.
1858. *N. unifasciata* Guérin-Meneville, Comptes Rendus, Nov. 23, 1857, p. 865. (From Annals & Mag. ref. below.)
1858. *N. unifasciata* Guérin-Meneville, Annals and Mag. of Nat. Hist. (3), I, p. 79. (Eng. review.)
1858. *N. unifasciata* Guérin-Meneville, Bull. Soc. Zoöl. Acclim. iv, p. 581, 1857.
1858. *N. unifaciata* Guérin-Meneville, Bull. Soc. Ento. Fr. (3) v, pp. cxlviii - cli.
1897. *N. unifasciata* Guérin; Kirkaldy, Trans. Ento. Soc. London for 1897, p. 426. (Says unknown to him.)
1898. *N. unifasciata* Guérin; Kirkaldy, Ento. Mon. Mag. (2) ix (Old ser., vol. xxxiv), p. 173. (Says: "doubtless *N. americana* Fabr.)
1899. *N. unifasciata* Guérin; Kirkaldy, Ento., xxxii, (Says = *N. undulata* Say.)
1917. *N. unifasciata* Guérin; Hungerford, Ento. News, xxviii, p. 181.
1929. *N. unifasciata* Guérin; Hungerford, Pan Pacific Ento., vi, No. 2, pp. 73-77. (Report on the type.)
1930. *N. unifasciata* Guérin; Hungerford, Can. Ento., lxii, p. 218.
1930. *N. unifasciata* Guérin; Hungerford, Bull. Brooklyn Ento. Soc., xxv, p. 139.
1933. *N. unifasciata* Guérin; Ancona, Anales del Inst. de Biol. IV, p. 68. (Mexico.)

Referring to this species, also:

1897. *N. americana* Kirkaldy, Trans. Ento. Soc. London for 1897, p. 409. (In part: Spec. Det. by him in Vienna and Paris.)
1899. *N. americana* Kirkaldy, Revue d'Entomologie, xviii, p. 94 (Desc. of egg).
1900. *N. indica* Kirkaldy, Ento., xxxiii, p. 10.
1901. *N. undulata* Champion, Biol. Centr. Amer., Hem.-Het., ii, p. 370 (in part).
1904. *N. indica* Kirkaldy, Wien, Ento. Zeit., xxiii, p. 95.
1905. *N. indica* Bueno, Jl. N. Y. Ento. Soc., xiii, pp. 149, 151; pl. vii, fig. 1.
1906. *N. indica* Snow, Trans. Kans. Acad Sci., xx, pt. 1, p. 181.
1909. *N. indica* Kirkaldy & Bueno, Proc. Ento. Soc. Wash., x, p. 198.
1916. *N. indica* Browne, Jl. Morph., xxvii, pp. 119-162. (Cytology.)
1917. *N. indica* Van Duzee, Catalogue Hemipt., p. 452.
1917. *N. indica* Hungerford, Ento. News, xxviii, p. 175.
1918. *N. indica* Hungerford, Ento. News, xxix, pp. 243, 245; pl. xv, fig. 11.
1919. *N. indica* Hungerford, Univ. Kans. Sci. Bull., xi, pp. 167, 168, 181, 332; pl. xxiii, fig. 11. (Ovipositor) pl. xxxi, fig. 6.
1928. *N. indica* Hungerford, Ento. News, xxxix, p. 156.

Size. Length, 9.3 mm. to 10.2 mm.; width of pronotum, 3.3 mm. to 3.6 mm.

Color. Typically black and white. Scutellum black with lateral margins flavous. Hemelytra white with black markings; clavus often black along inner margin and apex; distal end of corium and basal two-thirds of membrane crossed by solid black band.

Structural Characteristics. Anterior outline of head, as seen from above, somewhat flattened; vertex shorter than its anterior width; anterior margin of vertex less convex and longer than frontal margin of an eye; anterior breadth of vertex : synthlipsis :: 5:3. Pronotum slightly more than twice as long as the head; lateral margins nearly straight and moderately divergent; anterior angles somewhat acute

and embracing the eyes; lateral ledge oblique. Anterior lobe of membrane longer than the posterior. Anterior trochanter of male with medium-sized hook. Mesotrochanters angulate. Terminal abdominal sternite of female relatively broad and not plainly notched at tip. Female gonapophyses short. Male genital capsule as shown on Plate XIV.

Location of Types. Museum of Paris. Kirkaldy in his "Revision" listed the species as an "Unrecognized species," but I found the types in the Paris Museum in a box prepared by Guérin labeled "Hautlé." For a full report of this discovery see my paper in the Pan-Pacific Entomologist, volume VI, p. 73, 1929.

Comparative Notes. In general facies this is a characteristic species. The head is quite short, the black scutellum is margined with flavous and the mesotrochanter is angulate. There is some variation in the shape of the head, in the angle of the mesotrochanter and in the male claspers. The material from the type locality (near the city of Mexico), from Guadalupe, D. F. Mex., Socorro, N. M., and some specimens from Southern California, while showing some variation in the male claspers, appear to be *N. unifasciata* Guérin. The variations mentioned above make it necessary to designate subspecies as follows:

Notonecta unifasciata cochisiana new subsp.

This subspecies conforms to the general description of the species, but has a very characteristic male clasper that separates it from the typical *N. unifasciata* Guérin, see Plate XIV, fig. 5. Sixty specimens from Cochise Co., Arizona, represent the type series of this subspecies.

Notonecta unifasciata andersoni new subsp.

In this subspecies the anterior margin of vertex is more rounded and the clasper longer than in typical *N. unifasciata* Guérin. See Plate XIV, fig. 6. This is a smaller species than *N. spinosa* Hungerford, and although the shape of the head is somewhat like it the mesotrochanter does not have the long spine-like projection of the mesotrochanter so characteristic of *N. spinosa*. The type series was taken at Oliver, B. C. Material collected in Navajo, Ariz.; Carson City, Nevada; Lehi and Am. Forks, Utah; and Hot Lake, Oregon, shows a gradation away from the typical *N. unifasciata* Guérin.

Notonecta unifasciata angulata new subsp.

This subspecies conforms in general shape and appearance with the typical species, but the clasper of the male is stouter than any of the others. (See Pl. XIV, fig. 4.) The vertex of the female is more rounded. The mesotrochanter is angulate but not as produced. This subspecies is described from one male and one female in the Uhler Collection. The specimens bear the label "Kirkaldy, S. Amer."

Biological Notes. This species was described from a measure of dried insects offered for sale in Mexico as food. It formed part of a mixture of water bugs consisting largely of Corixids of two or three species, one of which Guérin described as new at the time he described this Notonectid. Collections of eggs of Corixids gathered and offered for food nearly always contain some eggs of this back-swimmer. C. T. Brues took this species and its nymphs from water having a temperature of 97.3° F. He took it from a number of hot springs with temperatures of 85° F. and above.

Data on Distribution. This species (broad sense) is widely distributed from Mexico, across Western United States to Western Canada. Two specimens labeled "S. Amer." in the Uhler collection appear to be a subspecies of *N. unifasciata* Guérin.

MEXICO

D. F. Texcoco Lake, Oct. 21, 1923, Jan. 31, 1926, Alf. Dampf; Ahuatle from Lake Texcoco, L. Ancona H., 9-1-1932; Guadalupe, D. F., Aug. 31, 1903, W.L. Tower; D. F. Lago de Texcoco, May 14, 1930, Creaser-Gordon. (Mich. U.)

UNITED STATES

TEXAS: Presidio Co., July 16, 1927, P. A. Readio; Valentine, July 13, 1927, R. H. Beamer.

NEW MEXICO: Torrance Co., Sept. 10, 1925, C. H. Martin; Estancia, Sept. 6, 1925, C. H. Martin; Socorro Co., Aug. 18, 1927, R. H. Beamer.

ARIZONA: Douglas, Aug., F. H. Snow; Navajo Co., Aug. 15, 1927, R. H. Beamer; Apache Co., Aug. 16, 1927, R. H. Beamer; Maricopa Co., Aug. 7, 1929, L. D. Anderson; Cochise Co., July 20, 1927, R. H. Beamer.

CALIFORNIA: L. Elsinore, Aug. 2, 1911; Los Angeles Co., Coquillett (U.S. N. M.); San Diego Co., Poway Val, Apr. 9, 1930, C. & D. Martin; Niles Canyon, Alameda Co.; San Antonio Canyon, Ontario, July 25, 1907; Kelly Springs, Camby, C. T. Brues; Cedarville, 1930, C. T. Brues; Bassetts Hot Springs, 1930, C. T. Brues.

NEVADA: Carson City, Aug. 9, 1929, Oman, Anderson and Beamer; Soda Lake, July 14, 1911; Fallon, Aug. 9, 1929, L. D. Anderson; 37 mi. s. of Battle Mts., Tem. 30°C., C. T. Brues; Goldfield, Tem. 35.4°C., C. T. Brues; 29 mi. s. of Winnemucca, Tem. 36.3°C., C. T. Brues (nymphs also); Sunnyside, 1930, C. T. Brues; Austin, Aug. 9, 1929, P. W. Oman.

UTAH: Emery Co., Aug. 26, 1921, Grace Wiley; Garfield, July 9, 1911, Locomotive Spgs., April 10, 1930, Grantsville, April 2, 1930, Pleasant Grove, April 4, 1930, Lehi, April 4, 1930, American Fork, April 8, 1930, all by G. F. Knowlton; Farwest, Sept. 12, 1929, C. J. D. Brown; Tremonton, July 5, 1931, L. D. Anderson.

OREGON: Hot Lake, Temp. 80° F., July 13, 1931, L. D. Anderson; Boardman, July 15, 1931, L. D. Anderson; Hood River, July 17, 1931, L. D. Anderson.

CANADA

Oliver, B. C., Aug. 6, 1931, L. D. Anderson; Peachland, Oct. 7, 1931, A. N. Gartrell; Brent's Lake, Summerland, Oct. 29, 1931, A. N. Gartrell; Vernon, June 21, 1921, R. Hopping; Penticton, Oct. 14, 1931, A. N. Gartrell; Westbank, April 21, 1932, A. N. Gartrell. (All but first in Ottawa Museum.)

Notonecta spinosa Hungerford, 1930

(Color Plate II, fig. 7; Plate XIV, fig. 7)

1930. *N. spinosa* Hungerford, Can. Ento., lxii, pp. 217, 218.

Size. Length, about 12 mm., the females may be a little longer and the males a little shorter than this. Width of pronotum, 3.3 mm. to 3.6 mm.

Color. General color of *N. undulata* Say except that the black scutellum is broadly margined with orange-yellow. It is therefore a black and white species with venter dark to black; the head, limbs and venter often suffused with green; dorsal view of head and anterior part of pronotum pale horn in color, posterior part of pronotum dark, due to black mesonotum beneath. Scutellum black, broadly margined with orange-yellow, the ends of this V-shaped figure slightly broader, not attaining the base of the scutellum. Hemelytra white with sooty black markings as follows: Small, dark, irregular blotch at base that may extend as narrow line to near the middle, one as a median dark line on the membrane; a zigzag M-shaped figure, which is thin, transversing hemelytra just in front of the membrane.

Structural Characteristics. Anterior outline of head, as seen from above, roundly curved; eyes not prominent; vertex with anterior width slightly greater than its length; anterior margin of vertex broadly rounded and wider than the frontal margin of an eye; anterior breadth of vertex : synthlipsis :: 2+:1. Length of pronotum : length of head :: 3+:2; lateral margins straight and divergent; anterior angles normal; lateral ledge oblique and shorter than the rear margin of the eye beneath it. Lobes of membrane about equal. Anterior trochanter of male with a hook. Mesotrochanter with angle produced into a long, sharp spine. Terminal abdominal

sternite of female with broad, but very shallow, notch at tip. Female gonapophyses (first pair) short. Male genital capsule as shown on Plate XIV.

Location of Types. Holotype, allotype and some paratypes in Francis Huntington Snow Entomological Museum in the University of Kansas. Other paratypes in U. S. National Museum; Canadian National Collection, Ottawa, Canada; Mus. of California Academy of Science and Knowlton's collection. Others have since been sent to Mr. Torre-Bueno, Mr. Esaki, the Paris Museum and the British Museum.

Comparative Notes. Size and color as in *N. undulata* Say except that the scutellum is always margined with orange-yellow. The more produced front margin of the vertex, the spinose mesotrochanter and the genitalia of both sexes separate it from Say's species. It is larger than *N. unifasciata* Guér., has a narrower synthlipsis and a long spinose mesotrochanter instead of angulate or slightly produced process as in Guérin's species.

Data on Distribution:

CANADA

BRITISH COLUMBIA: Vernon, Sept. 26, 1919, W. Downes (Ottawa, Canada); Oliver, Aug. 6, 1931, L. D. Anderson.

UNITED STATES OF AMERICA

UTAH: Lehi, April 4, 5, 8 and May 3-27 1930, G. F. Knowlton; Logan, Oct. 5, 1930, M. J. Jones; Hyde Park, April 19, 1930, G. F. Knowlton; Brigham, April 26, 1930, G. F. Knowlton; American Fork, May 3, 1930, G. F. Knowlton.

NEVADA: Carson City, Aug. 9, 1929, R. H. Beamer.

YELLOWSTONE NATIONAL PARK: Fry Pan L., Aug. 15, 1931, L. D. Anderson.

MONTANA: Whitehall, Aug. 13, 1931, L. D. Anderson; Three Forks, July 22, 1931, L. D. Anderson.

OREGON: Hot Lake, July 13, 1931, L. D. Anderson.

Notonecta indica Linné, 1771

(Color Plate I, fig. 2; Plate XIII, fig. 3)

1771. *N. indica* Linnæus, Mantissa Plantarum, ii, p. 534.
1806. *N. indica* Linnæus; Turton *in* Linn. Syst. Nat., edn. 13, Eng. Transl., ii, p. 605.
1930. *N. indica* Linnæus; Hungerford, Bull. Brook. Ento. Soc., xxv, p. 139.

Referring to this species, also:

1775. *N. americana* Fabricius, Syst. Ento., p. 690.
1811. *N. americana* Olivier, Encyclopédie Méthodique Histoire Naturelle Insectes, viii, pp. 387 and 389, "Saint Domingue."
1832. *N. undulata* Say, N. Harm., p. 39; Fitch reprint, p. 812; Compl. Writ. I, p. 368 (in part).
1851. *N. variabilis* var. *scutellaris* Fieber, Rhynchotographieen, p. 477. (Those from Portorico.)

1856. *N. variabilis* Guérin, in Ramon de la Sagra's Cuba, Hist. Nat., vii, p. 176.

1881. *N. pallipes* Lethierry, Ann. Soc. Ento. Belg., xxv, p. 13 (three specimens from St. Barthélemy).

1884. *N. undulata* Uhler, Standard Nat. Hist. II, p. 252 (in part.)

1891. *N. undulata* Summers, Bull. Agri. Exp. Sta., Univ. Tenn., iv, No. 3, p. 82 (in part).

1894. *N. americana* Uhler, Proc. Zoöl. Soc. London for 1894, p. 223 (a single nymph taken Aug. 20).

1897. *N. undulata* Kirkaldy, Trans. Ento. Soc. London, p. 410 (in part).

1897. *N. undulata* var. *charon* Kirkaldy, Trans. Ento. Soc. London, p. 411 (in part).

1899. *N. undulata* Kirkaldy, The Ento., xxxii, p. 29 (Flight to lights in Jamaica).

1901. *N. undulata* Champion, Biol. Centr. Amer. Hem. Het., ii, p. 370, Tab. xxii, fig. 10.

1905. *N. howardii* Bueno, Jl. N. Y. Ento. Soc., xiii, p. 151.

1905. *N. undulata* Bueno, Jl. N. Y. Ento. Soc., xiii, p. 153 (in part).

1909. *N. undulata* Delcourt, Bull. Sci. Fr. et Belg, Tom xliii (7), vol. 1, pl. iv, line 8.

1909. *N. undulata* Kirkaldy & Bueno, Proc. Ento. Soc. Wash., x, p. 199 (in part).

1909. *N. howardii* Bueno; Kirkaldy & Bueno, Proc. Ento. Soc. Wash., x, p. 198 (in part).

1914. *N. undulata* Barber, Bull. Am. Mus. Nat. Hist., xxxiii, p. 499.

1917. *N. undulata* Van Duzee, Catalogue Hemiptera, p. 451 (in part).

1917. *N. howardii* Bueno; Van Duzee, Catalogue Hemiptera, p. 452.

1919. *N. howardii* Bueno; Hungerford, Kans. Univ. Sci. Bull., xi, p. 168.

1919. *N. undulata* Hungerford, Kans. Univ. Sci. Bull., xi, p. 169 (in part).

1922. *N. howardii* Bueno; Hungerford, Kans. Univ. Sci. Bull., xiv, p. 426. (Says fig. 8, pl. xxxi of Sci. Bull. xi is this species).

1922. *N. howardii* Bueno; Drake, Ohio Jl. Sci., xxii, p. 116.

1926. *N. howardii* Bueno; Blatchley, Heteroptera . . . p. 1053.

1926. *N. undulata* Blatchley; Blatchley, Heteroptera . . . p. 1054 (in part).

1928. *N. howardii* Bueno; Hungerford, Ento. News, xxxix, p. 156 (Georgia).

Size. Length, 10 mm. to 11 mm.; width of pronotum, 3.36 mm. to 3.75 mm.

Color. Color variable, from luteous to nearly black, the hemelytra having only the base of the clavus tan. The typical color is black and white; the scutellum and a broad band covering the distal end of corium and the basal two-thirds of the membrane black; the scutellum often pale at tip and marked near each basal angle by a light spot.

Structural Characteristics. Head more than one-half length of pronotum; vertex as long or slightly longer than its anterior width as seen from above; anterior margin of vertex less convex and shorter than the frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 5:2; synthlipsis about two-fifths the width of the eye. Pronotum not twice length of head, lateral margins but slightly divergent on anterior two-thirds, then divergent, making the lateral margin appear concave and yet giving the appearance of a somewhat parallel sided pronotum; anterior angles embracing the eye; lateral ledge but slightly oblique and straight. Lobes of membrane equal. Anterior trochanter of male with a stout conspicuous hook. Mesotrochanter rounded. Terminal abdominal sternite of female with a shallow notch or none at tip. Female gonapophyses short. Male genital capsule as shown on Plate XIII.

Location of Type. I did not find any specimens in Upsala, Sweden, but in the Collection of the Linnean Society at London there is a male specimen. It lacks one middle leg entirely and the tibia and tarsus of the other. It still has both front legs and one hind leg (1928). The specimen has a black scutellum with flavous marks, which are irregular, as in many specimens of what we have heretofore known in America as *N. howardii* Bueno. The mesotrochanter is rounded as in Bueno's species, not angulate as in *N. unifasciata* Guér, which we called *N. indica* for many years. The label "indica" appears not to be in Linnæus handwriting. It is, however, altogether probable that this specimen was in the Linnæan collection purchased by Sir James E. Smith, who was for forty years president of the Linnean Society of London. I therefore designate it the type of *N. indica* Linn.

In the Museum at Copenhagen, under the name *Notonecta americana* Fabr., I found several specimens. The first one bears the labels: "Museum Seh. and T. Lund," "*N. americana*" and is *N. indica* Linn. It is a female specimen and the scutellum has the pale spot at each basal corner as described by Fabricius (Fabricius, however, said his specimen was from "Mus. Tottianum"). The second specimen bears one label I cannot read and another "Mus. Seh. and T. Lund." It is *N. undulata* Say. The third and fourth specimens are females labeled "Mus. Westerm" "*N. americana*" and are *N. indica* Linn. There is no doubt that the first two specimens at least were seen by Fabricius and the first one fits his description exactly.

Comparative Notes. Due to its size and color variations it has been included under *N. undulata* Say in most collections. The broad black band across the hemelytra of typical specimens separate it from typical specimens of *N. undulata* Say. The head is more truncate as seen from above. The shape of the pronotum appears more parallel sided than in Say's species. The last abdominal sternite of the female is shallowly notched, if notched, and the anterior trochanters of the male are armed with larger hooks than in *N. undulata* Say.

Data on Distribution. This is one of the few species common to both North and South America. Its range extends across the southern United States south of 37° latitude. I have seen but one collection north of this line. This is from Maryland, which indicates that east of the Allegheny Mountains it extends northward to include Maryland. Southward I have it from Mexico, Yucatan, Guate-

mala, Colombia, South America (Bogota), Brazil * ?, and from the Islands of Cuba, Jamaica, St. Croix, St. Thomas, and Porto Rico.

The following collections are before me:

UNITED STATES OF AMERICA

MARYLAND: Crisfield, Sept. 26, U. S. N. M. (Uhler called it *N. punctata* Fieb.).

NORTH CAROLINA: Southern Pines, Sept. 14, 1916.

SOUTH CAROLINA: Clemson College, April 13, 1929, Oct. 30, 1927, Nov. 25, 1929, D. Dunavan; Walhalla, Mar. 24, 1929, D. Dunavan.

KENTUCKY: Pond near Brooklyn Bridge, Jan. 3, 1933, H. Garmen, (taken along with *N. undulata* Say.)

TENNESSEE: Murfreesboro, Aug. 29, 1929, Creaser & Becker (Michigan); Knoxville, July 13, 1890; Neubert Springs, Dec. 1, 1932, L. Chester Marsten Jr. (34 adults and 3 nymphs).

GEORGIA: Baker Co., Aug. 24, 1927, C. H. Martin; Ga. (Uhler Coll. U. S. N. M.).

FLORIDA: Inverness, Aug. 1, 1930, J. O. Nottingham; Cocoanut Co., Aug. 9, 1930, R. H. Beamer; Archer, July 31, 1930, Paul Oman; Sanford, Aug. 4, 1930, Paul Oman; Wildwood, Aug. 2, 1930, J. O. Nottingham; Plant City, Jan. 4, 1927, C. O. Bare; Dunedin, W. S. Blatchley, Feb. 9, 1919 (Purdue Univ.).

MISSISSIPPI: Fayette, July 23, 1921; Miss. Agri. Coll., Aug. 20, 1913, J. G. Hester; Natchez, Sept. 8, 1924, H. M. Harris.

LOUISIANA: Baton Rouge, Mar. 9, 1929, R. M. DeCoursey; Mound, Mar. 9, 1929; Opelousas, C. R. Pilate (Baker Coll. U. S. N. M.); New Orleans, July, 1916, H. E. Hubert (U. S. N. M.).

ARKANSAS: Arkansas Co., Apr. 9, 1930; Fayetteville, Feb. 27, 1930; Lawrence Co., B. C. Marshall; Imboden, Mar. 19, 1925, B. C. Marshall.

TEXAS: Hidalgo Co., July 30, 1928, R. H. Beamer; Sutton Co., July 16 and Aug. 20, 1928, R. H. Beamer; Victoria Co., Aug. 9, 1928, R. H. Beamer; Victoria, Dec. 27, 1910, J. D. Mitchell (U. S. N. M.); Colorado Co., Apr. 25, 1922, Grace Wiley; Cameron Co., Aug. 13, 1928, A. M. James; Brooks Co., July 25, 1928, R. H. Beamer; Jim Wells Co., July 24, 1928, A. M. James; Valentine, July 13, 1927, R. H. Beamer; Kerrville, Apr. 11, 1907, F. C. Pratt; Calvert, July 22, 1907, C. R. Jones (U. S. N. M.); Alfred, July 24, 1932, R. H. Beamer.

NEW MEXICO: Socorro Co., Aug. 18, 1927, L. D. Anderson; Eddy Co., July 9, 1927, P. A. Readio; San Antonio, July 15, 1927, L. D. Anderson; Mesilla Park, July 18, 1927, P. A. Readio.

ARIZONA: Douglas, F. H. Snow; Gila Co., Aug. 5, 1927, R. H. Beamer; Cochise Co., July 29, 1927, L. D. Anderson; S. W. edge Tuscon, July 20, 1932, R. H. Beamer.

CALIFORNIA: Holtville, July 2, 1929, R. H. Beamer; Calipatria, July 14, 1923.

* See p. 141 where I have called these Fieber's *N. variabilis*.

MEXICO

Tamaulipas, San Carlos Mts., July, 1930, Dice & Bartlett (Michigan); Los Mochis, Senaloa, June 13, 1922, C. T. Dodds; Cuernavaca, Nov. 4, 1922, E. G. Smyth (U. S. N. M.); Guadalajara, Etat de Jalisco, M. Diguet, 1901 (labeled *N. undulata* var. *charon* Am. M. N. H.); Yucatan, Tabi, F. D. G. (labeled "B. C. A. Rhyn. II. *N. undulata* Say" U. S. N. M.).

GUATEMALA

S. Geronimo, Champion B. C. A. Rhyn II (labeled "*N. undulata* by Champion); Guatemala City, Ainslei (C. J. Drake).

COLOMBIA

Bogota, Coll. Signoret (Vienna); Colombie, Steinheil (det. by Kirkaldy as *N. undulata* Paris Mus.).

WEST INDIES

CUBA: Havana, Jan. 25, 1932, P. J. Bermudez; Havana, Baker (U. S. N. M); Soledad, Apr. 4, 1925, J. G. Myers; Littletown, Jan. 1, 1878.

JAMAICA: Claremont Baron Hill, Trelawny, Mar. 4, 1928, L. G. Perkins; Montego Bay, Mar. 15, 1911 (Am. Mus. Nat. Hist.); Port Antonio, A. E. Wight (Mus. Comp. Zoöl., Cambridge, Mass.); Yardley Chase, Santa Cruz Mts., St. Elizabeth, taken at light Oct. 31, 1899.

PORTO RICO: Desengano, June, 1924 (Cornell Univ. lot 719).

ST. THOMAS: Charlotte Amalie; V. Ids., June 2, 1917, Harold Morrison.

ST. CROIX: "F. 5022," Mar. 4, 1925 (Am. Mus. Nat. Hist.).

Notonecta undulata Say, 1832

(Color Plate I, fig. 3; Plates IX, fig. 3; X, fig. 3; XIII, fig. 1)

1832. *N. undulata* Say, Heter. New Harm., p. 39; Fitch's reprint, p. 812: Complete Writ. I, p. 368.

1851. *N. undulata* Say; Fieber, Rhynchotographieen p. 479 (not known to him). Rhynchotographien, p. 55 (Van Duzee).

1853. *N. undulata* Say; Herrick-Schäffer, Wanzenartigen Insecten, ix, p. 137.

1874. *N. undulata* Say; Packard, Half hours w. Insects, pt. 6, pp. 139-141, fig. 103 (Egg desc. p. 158).

1876. *N. undulata* Say; Uhler, Bull. U. S. Geol. Geog. Surv., vol. I, Bull. V, 2d ser., p. 339, pl. 21, fig. 33.

1876. *N. undulata* Say; Uhler, Bull. U. S. Geol. Geog. Surv. Reprint from above, p. 73. (Inhabits foulest pools.)

1877. *N. undulata* Say; Uhler, Bull. U. S. Geol. Geog. Surv., III, p. 453.

1877. *N. undulata* Say; Uhler, Wheeler's Rept. Chief Eng. for 1877, p. 1332. (N. Mex.)

1878. *N. undulata* Say; Uhler, Bull. U. S. Geol. Geog. Surv., iv, p. 509.

1878. *N. undulata* Say; Uhler, Proc. Bost. Soc. Nat. Hist., xix, p. 442. (Except Var. Σ.)

1878. *N. undulata* Say; Packard's Guide, 6th Ed., p. 537, fig. 542.

1884. *N. undulata* Say; Uhler, Stand. Nat. Hist., II, p. 252 (in part.)

1884. *N. undulata* Say; Popenoe, Trans. Kans. Acad. Sci., ix, p. 62.

1888. *N. undulata* Say; Comstock, Introduction, p. 186, fig. 157.

1888. *N. undulata* Say; Provancher, Pet. Faune Ent. Can., iii, p. 201.

1889. *N. undulata* Say; Weed, Bull. Ohio. Agri. Sta. Tech., ser. I, p. 12; pl. ii, fig. 3 (Feeding and defense).

1889. *N. undulata* Say; Garman, Bull. Ill. Lab. N. H., Art. ix, vol. iii, p. 174.

1890. *N. undulata* Say; Hyatt and Arms, Insecta, p. 121, fig. 70.

1891. *N. undulata* Say; Summers, Bull. Agr. Exp. U. of Tenn., iv, No. 3, p. 82.

1894. *N. undulata* Say; Uhler, Proc. Calif. Acad. Sci. (2) iv, p. 292.

1894. *N. undulata* Say; Van Duzee, Bull. Buffalo Acad. Nat. Sci., v. p. 186.

1895. *N. undulata* Say; Gillette & Baker, Bull. xxxi, Colo. Agr. Exp. Sta. Tech. ser. i, p. 63.
1897. *N. undulata* Say; Kirkaldy, Trans. Ento. Soc. London for 1897, p. 410.
1897. *N. undulata* Say; Smith, Ins. N. J., p. 144.
1899. *N. undulata* Say; Packard, Ento. for Beginners, p. 83.
1899. *N. undulata* Say; Comstock, Manual, p. 130, fig. 49.
1900. *N. undulata* Say; Osborn, Contr. Dept. Zoöl. and Ento. Ohio State Univ., No. 2, p. 79.
1900. *N. undulata* Say; Lugger, Bull. 69, Ento. Div. U. of Minn. Agr. Coll. Exp. Sta, p. 15.
1901. *N. undulata* Say; Champion, Biol. Centr. Amer. Hem.-Het., ii, p. 370 (in part).
1901. *N. undulata* Say; Howard, Insect Book., p. 275.
1902. *N. undulata* Say; Bueno, Jl. N. Y. Ento. Soc., x, pp. 231 and 233.
1904. *N. undulata* Say; Kirkaldy, Wien. Ento. Zeit., xxiii, pp. 94, 95 and 132 (in part).
1905. *N. undulata* Say; Bueno, Jl. N. Y. Ento. Soc., xiii, p. 45 (in part).
1907. *N. undulata* Say; Bueno and Brimley, Ento. News, xviii, p. 435.
1908. *N. undulata* Say; Bueno, Jl. N. Y. Ento. Soc., xvi, p. 238.
1909. *N. undulata* Say; Kirkaldy & Bueno, Proc. Ento. Soc. Wash., x, p. 199 (in part).
1909. *N. undulata* Say; Delcourt, Bull. Sci. Fr. et Belg., xliii, (7) I, pl. iv, line 6, No. 5; line 7, Nos 1, 2, 3, 4.
1910. *N. undulata* Say; Bueno, Jl. N. Y. Ento. Soc., xviii, p. 33. (Dec. and Feb. swimming under thin ice.)
1910. *N. undulata* Say; Severin, Can. Ento., xlii, p. 340. (Food habits.)
1910. *N. undulata* Say; Smith, Catalog Ins. N. J., edn. 3, p. 169.
1912. *N. undulata* Say; Bueno, Can. Ento., xliv, p. 213.
1913. *N. undulata* Say; Browne, Jl. Exp. Zoöl., xiv, p. 61. (Male germ cells.)
1914. *N. undulata* Say; Barber, Bull. Am. Mus. Nat. Hist., xxxiii, p. 499. (Cited in error.)
1914. *N. undulata* Say; Parshley, Psyche, xxi, p. 140. (May 8, Oct. 17, Orono, Maine.)
1917. *N. undulata* Say; Hungerford, Ento. News, xxviii, pp. 175-182; pl. xiii, fig. 7.
1917. *N. undulata* Say; Hungerford, Ento. News, xxviii, pp. 267-277; pls. xix and xx. (Life history.)
1917. *N. undulata* Say; Parshley, Occ. Papers Boston Soc. Nat. Hist., vii, p. 113.
1917. *N. undulata* Say; Van Duzee, Catalog, Hemipt., p. 451, 452 (in part).
1918. *N. undulata* Say; Hungerford, Ento. News, xxix, pp. 242, 243, 245; pl. xv, fig. 3 (ovipositor).
1919. *N. undulata* Say; Parshley, Occ. Papers Mus. Zoöl. Univ. Mich., No. 71, 1919.
1919. *N. undulata* Say; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 21, 96, 166-169, 177, 180, 181, 184, 186, 187, 190, 193, 195, 196, 258, 259, 263, 268. Color Plate II, fig. 1 and pls. i, iv, viii, xix, xx, xxi, xxiii, xxiv. (Biology of.)
1919. *N. undulata* Say; Hungerford, Kans. Univ. Sci. Bull., xi, pp. 329, 332; pl. xxxi, fig. 10.
1921. *N. undulata* Say; Parshley, Proc. British Columbia Ento. Soc., No. 18 (Syst. Ser.), p. 24.
1922. *N. undulata* Say; Parshley, S. Dakota St. College Tech. Bull. II, p. 22.
1923. *N. undulata* Say; Bueno & Hussey, Bull. Brooklyn Ento. Soc. xviii, p. 107.
1923. *N. undulata* Say; Bueno, Conn. St. Geol. & Nat. His. Surv. Bull. No. 34, pp. 404 and 405. (April to Oct.)
1924. *N. undulata* Say; Hale, Proc. Lin. Soc. N. S. Wales, xlix, pt. 4, p. 462.
1925. *N. undulata* Say; Hungerford, Annals Ento. Soc. Amer., xxviii, p. 417.
1925. *N. undulata* Say; Comstock, Introduction to Ento., p. 362, fig. 416.
1925. *N. undulata* Say; Clark, Bull. Brooklyn Ento. Soc., xx, pp. 186 and 187.
1925. *N. undulata* Say; Hungerford & Beamer. Ento News, xxxvi, pp. 263, 264, 297.
1926. *N. undulata* Say; Leonard, Cornell Univ. Agri. Exp. Sta. Memoir 101, p. 139. (March to Nov.)
1926. *N. undulata* Say; Bare, Annals Ento. Soc. Amer., xix, p. 93. (Life history.)
1926. *N. undulata* Say; Hungerford, Bull. Brooklyn Ento. Soc., xxi, p. 195.
1926. *N. undulata* Say; Blatchley, Heteroptera . . . p. 1053.
1928. *N. undulata* Say; Hungerford, Annals Ento. Soc. Amer., xxi, pl. ix, fig. 4.
1928. *N. undulata* Say; Hungerford, Ento. News, xxxix, p. 156. (From N. M.)
1929. *N. undulata* Say; Hutchinson, Annals S. Afr. Mus. xxv, pt. 3, p. 364.
1930. *N. undulata* Say; Hungerford, Bull. Brooklyn Ento. Soc., xxv, p. 138.

Referring to this species, also:

1847. *N. glauca* Shepherd,* Sillimans Amer. Jl. (2) iv, pp. 423, 424 (migration).

1848. *N. glauca* Shepherd, Ann. & Mag. Nat. Hist. (2) I, p. 158.

1848. *N. glauca* Simpson, Quoted by Spence *in* Trans. Ento. Soc. London, v, proc. p. 36.

1851. *N. punctata* Fieber, Rhynchotographieen, p. 476. Rhynchotographien, p. 52. (Van Duzee.)

1853. *N. americana* Herrick-Schaeffer, Wanzen. Ins., ix, p. 44, fig. 902. (Color illus.—not typical for any species.)

1897. *N. undulata* var. *charon* Kirkaldy, Trans. Ento. Soc. London for 1897, p. 411 (in part).

Size. Length, 10.5 mm. to 12.6 mm.; width of pronotum, 3.6 mm. to 4 mm.

Color. Typically black and white. Head and legs of usual color, often greenish; abdominal venter usually marked with black areas; connexivum like the legs; thoracic venter dark; posterior part of pronotum darkened by the black mesonotum beneath. Scutellum black. Hemelytra white with an undulate transverse black band across apex of corium and base of membrane. The species may vary from pale luteous forms with pale scutellum to forms darker than typical, having, beside the usual black marks, distal end of clavus, a band on middle of corium and a streak on embolium nearly black. All gradations occur.

Structural Characteristics. Anterior outline of head, as seen from above, somewhat rounded; vertex about as long as its anterior width; anterior margin of vertex slightly less convex and longer than frontal margin of an eye; anterior breadth of vertex : synthlipsis :: 2 + :1. Pronotum less than twice as long as the head; lateral margins straight and moderately divergent; anterior angles slightly embracing the eyes; lateral ledge oblique. Lobes of membrane about equal. Anterior trochanter of male with a medium-sized hook. Mesotrochanter not angulate. Terminal abdominal sternite of female notched at tip, the notch deeper than wide. Female gonapophyses (first pair) short. Male genital capsule as shown on Plate XIII.

Location of Type. In the T. W. Harris collection at the Boston Society of Natural History are the specimens reported by Doctor Uhler in the Proceedings of the Boston Society of Natural History XIX, pt. 4, Apr., 1878, p. 442. In this paper, entitled "Notices of the Hemiptera Heteroptera in the Collection of the late T. W. Harris," Doctor Uhler writes concerning *N. undulata* Say: "No. 17 β Harris collection "Rivers and Ponds. Sept. 20, 1821. May 15, 1828 ♂, ♀." Determined by Mr. Say. Four varieties remain in the collection,

* This and two following relate to a flight of backswimmers in the upper Mississippi valley, probably *N. undulata* Say, but cannot be certain.

noted β. γ. δ Σ . . ." The remaining notes by Uhler are of little interest now except to show that his own idea of the species included *N. lunata* Hungerford and *N. indica* Linn. I have examined the specimens mentioned above. β. is typical. γ. is less colored, the scutellum is yellow margined, and there is a small black spot on outer tip of embolium and corium. δ has lost its head and pronotum, the wings are pale and there is a central spot of black on scutellum. Σ is *N. lunata* Hungerford.

There can be no doubt as to the identity of Say's *N. undulata* which he described from "Missouri and Indiana." The species I have described is not only the most common species in the regions he names, but the most common and widespread back-swimmer in the United States. It is the only one with the typical undulate band and has been recognized by all American students. I have specimens from Missouri that fit Say's original description. There can be no objection in designating β. which was determined by Say as the type of *N. undulata* Say.

Comparative Notes. Kirkaldy included several distinct species under this name which lead him to give a distribution extending all the way down to Chile, S. A. There are in North America several black and white species of approximately the same size, and when pale specimens are encountered they have often been confused with *N. lunata* Hungerford. The rounded mesotrochanter separates *N. undulata* Say from *N. lunata* Hungerford, *N. unifasciata* Guér. and *N. spinosa* Hungerford, which have angulate to spinose mesotrochanters. The straight, divergent lateral margins of the pronotum, the moderate size of the hook on the anterior trochanter of the male, and the deep, narrow notch in the last abdominal sternite of the female separate it from *N. indica* Linn., which has lateral margins of the pronotum curved, conspicuous hook on anterior trochanter of male and a shallow notch, or none, in the last abdominal sternite of the female. (See, also, the key to species on page 68.)

Biological Notes. This common species has been the subject of several studies in behavior and life history. In 1917 Hungerford described and figured the elongate white egg, which is attached to submerged objects, and the five nymphal instars. In the earlier instars the food consists largely of ostracods and similar organisms. Winter is passed in the adult stage, and in Kansas there are two main broods in a season. Bare (1926) obtained the emergence of an adult in the laboratory on July 30, and 13 days later it began lay-

ing eggs. He also reared the species to maturity in from forty to fifty-two days, using mosquito larvæ as food.

Data on Distribution. This North American species ranges from coast to coast and from Canada to the Gulf. It is the most common species of the back swimmers east of the Rocky Mountains and north of the 37° of latitude. South of this line it is more and more replaced in abundance by *N. indica* Linn. as one goes southward. My data include the following:

CANADA

NOVA SCOTIA: Truro, Sept. 23, 1926, F. Johansen.

QUEBEC: Fairy Lake, May 14, 1927, and Sept. 11, 1928, G. S. Walley; Kazubazua, Aug. 18, 1927, and Aug. 28, 1928, W. J. Brown, and Aug. 18, 1931, G. S. Walley; Otter Lake, Aug. 6, 1931, G. S. Walley; Knowlton, June 21, 1927, G. W. Walley.

ONTARIO: Rockcliffe, Aug. 2, 1928, G. H. Fisk; Mer Bleue, May 28, 1927, G. S. Walley; Westboro, Sept. 10, 1928, J. A. Adams; Toronto, Sept. 18, 1930, L. J. Milne; Rondeau Park, June 13, 1929, G. S. Walley; Pt. Pelee, June 6, 1929, G. S. Walley; Ventnor, Aug. 1, 1928, J. A. Adams.

MANITOBA: Aweme, July 6, 1922, N. Criddle; Treesbank, Aug. 15, 1922, N. Criddle.

ALBERTA: Lethbridge, May 8-13, 1920, J. H. Pepper.

BRITISH COLUMBIA: Peachland, Oct. 7, 1931, A. N. Gartell; Wellington; Victoria, June 6, 1923, K. F. Auden; Chilliwack, Sept. 20, 1925 (Univ. of Kans.); Mt. Cheam, Sept. 13, 1924 (Univ. of Kansas); Van Couver Island, Saanich Dist., Sept. 1, 1917, W. D. (Rept. by Parshley, 1919) Oliver; Aug. 6, 1931, L. D. Anderson (Univ. of Kansas).

All above Canadian records from material in Ottawa, Canada, unless otherwise stated.

UNITED STATES

MAINE: Orono, May 8 to Oct. 17 (see H. M. Parshley).

MASSACHUSETTS: Amherst, May 16, 1922.

RHODE ISLAND: Providence (Bueno Coll.).

CONNECTICUT: Apr. 9 to Oct. 24 (see Conn. Geol. and Nat. Hist. Surv. Bull. 34).

NEW YORK: Long Island, May; Ithaca, Nov. 19, 1921, P. W. Claassen.

NEW JERSEY: Rancocas, Aug. 29, 1927, E. M. Becton.

PENNSYLVANIA: Rockville, Apr. 1, 1917, J. G. Sanders (C. J. Drake).

VIRGINIA: Warrenton, June 7, 1928, L. Woodruff.

KENTUCKY: Pond near Brooklyn Bridge, Jan. 3, 1933, H. Garman (taken along with *N. indica* Linn.).

OHIO: Columbus, Oct. 2, 1914, C. J. Drake; Zanesville, Aug. 10, 1915, C. J. Drake.

MICHIGAN: Cheboygan Co., July 12 and 31, H. B. Hungerford; Mackinac Island, Aug. 19, 1925, H. B. Hungerford; Nigger Creek, Mullett L., Aug. 4, 1925, H. B. Hungerford; Bois Blanc Island, Aug. 14, 1932, H. B. Hungerford.

Many other collections near Douglas L., Cheboygan Co., by H. B. Hungerford, covering ten summers.

INDIANA: Kosciusko Co., July, 1932, G. E. Gould (Purdue Univ.).

ILLINOIS: Normal, June 22, 1883; Towanda Pond, April, 1882; Havana, July 7, 1910, and many other records in Illinois Nat. Hist. Surv. Mus.

WISCONSIN: Lone Rock, Aug. 14, 1906.

MINNESOTA: Bengal, Aug. 18, 1922, H. B. Hungerford; Becker Co., Aug. 22, 1922, H. B. Hungerford; Beaver Dam, Minn., Aug. 12, 1922, H. B. Hungerford; Itasca Park, Aug. 21, 1922, H. B. Hungerford.

IOWA: Ames, Oct. 11, 1924, H. M. Harris.

MISSOURI: Kansas City, F. Rogers; St. Louis, April, 1900, J. Abbott; Columbia, Nov. 24, 1911, J. F. Abbott.

ARKANSAS: Arkansas Co., Oct. 6, 1930, D. Isely; Fayetteville, Nov. 14, 1929, D. Isely.

TEXAS: Sutton Co., Aug. 20, 1928, A. M. James; Eastland Co., Jan. 2, 1921, Grace Wiley; Randall Co., July 7, 1927, R. H. Beamer; Valentine, Aug. 13, 1927, R. H. Beamer; Presidio Co., July 16, 1927, R. H. Beamer.

OKLAHOMA: Ardmore, April 14, 1923, H. B. Hungerford; Grant Co., Feb. 20, 1921, W. E. Hoffmann.

KANSAS: Doniphan Co., Aug. 27, 1921, W. J. Brown; Leavenworth Co., Feb. 6, 1921, W. E. Hoffmann; Douglas Co. (every month of the year); Riley Co., Oct. 1920, H. B. Hungerford; Allen Co., Apr. 24, 1921, W. E. Hoffmann; Woodson Co., Feb. 24, 1921, W. E. Hoffmann; Cowley Co., Mar. 16, 1921, W. E. Hoffmann; Lyons Co., June 18, 1923, Herbert Darby; Linn Co., 1915, R. H. Beamer; Comanche Co., June 19, 1927, H. B. Hungerford; Meade Co., (no data); Morton Co., Aug. 4, 1924, C. O. Bare; Scott Co., June 22, 1929, Howard Deay; Cheyenne Co., summer, F. X. Williams.

SOUTH DAKOTA: Sand Hills, Martin, Sept. 15, 1930, H. C. Severin; Brookings, June 4, 1928, H. C. Severin; Springfield, June 15, 1928, L. Hendricks, July 12, 1922, H. C. Severin (S. D. St. College.)

MONTANA: Three Forks, July 22, 1931, L. D. Anderson.

IDAHO: Caldwell, May 9, 1926, C. J. Drake.

COLORADO: Estes Park, Aug. 22, 1919, H. B. Hungerford; Pingree Park, Aug. 21, 1926, R. H. Beamer; Las Animas Co., Aug. 22, 1927, P. A. Readio; Lamar, Aug. 22, 1927, P. A. Readio; La Junta, Aug. 22, 1927, L. D. Anderson; Boulder, June 28, 1931, L. D. Anderson; Caisson, July 1, 1931, L. D. Anderson; Ft. Collins, Aug. 19, 1898.

UTAH: Farwest, Sept. 12, 1924, C. J. D. Brown; Emery Co., Aug. 26, 1921, Grace Wiley; Antelope, July 1, 1931, L. D. Anderson.

NEW MEXICO: Socarro Co., Aug. 18, 1927, L. D. Anderson; Torrance Co., Sept. 10, 1925, C. H. Martin; Santa Cruz Co., Aug. 20, 1927, R. H. Beamer; Estancia, Sept. 6, 1925, C. H. Martin.

ARIZONA: Gila Co., Aug. 6, 1927, P. A. Readio; Navajo Co., Aug. 15, 1927, P. A. Readio; Cochise Co., July 29, 1927, R. H. Beamer; Coconini Co., Aug. 13, 1927, P. A. Readio.

CALIFORNIA: Calipatria, July 14, 1923.

NEVADA: Carson City, Aug. 9, 1929, R. H. Beamer.

OREGON: Hot Lake, July 13, 1931, L. D. Anderson; Corvallis, June 26, 1926, C. J. Drake.

WASHINGTON: Kalama R., July 21, 1931, L. D. Anderson; Takoma (Hamburg, Germany).

I lack material from the following states: Maryland, District of Columbia, West Virginia, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Nebraska, North Dakota, Wyoming.

MEXICO

San Antonio, July 15, 1927, L. D. Anderson.

Notes on *Notonecta punctata* Fieber, 1851

Doctor Fieber described this from Baltimore, North America. Without doubt it is *N. undulata* Say and Kirkaldy was correct in so considering it. Fieber does not mention the museum where the insects belong. There are in the Zoölogical Museum in Berlin 4 specimens under the name *N. punctata* Fieber. They are labeled as follows:

First. "3624" "Mexico Deppe" "punctata Fieb." (This is near *N. shooteri* Uhl. Fieber's type was from Baltimore.)

Second. Label like the first but lacking determination label.

Third. "Cat. N. 3624" "Mexico, Deppe." This is not *N. shooteri*, a smaller species with rounded trochanter.

Fourth. "7195" "Mexico." This is near *N. shooteri* Uhler.

All of the above coming from Mexico cannot be Fieber's types.

Notonecta indicoidea Hungerford, 1927

(Color Plate II, fig. 2; Plate XIV, fig. 8)

1927. *N. indicoidea* Hungerford, Bull. Brookl. Ento. Soc. XXII, p. 250.

Referring to this species, also:

1897. *N. undulata* var. *charon* Kirkaldy. Trans. Ento. Soc. London, p. 411 (in part). In Stockholm Mus. lab. by Kirkaldy.

1897. *N. shooterii* Kirk. Trans. Ento. Soc. London, p. 408 ("Two handsome Notonectæ from Guanajuata in Mex. Dugés in Mus. Paris").

Size. Length, 10.8 mm. to 11 mm.; width of pronotum, 3.9 mm.

Color. General facies dark. Head, anterior half of pronotum and limbs yellow. Rear half of pronotum darkened by the black mesonotum beneath. Scutellum black. Hemelytra black, save two oblique tan streaks near base of corium and clavus and tip of membrane, which is pale. Venter black except connexivum and a spot on median line of fourth and fifth abdominal sternites.

Structural Characteristics. Head and eyes not prominent; anterior outline of head rather flattened; vertex subequal to shorter than its anterior width; anterior margin of vertex less convex than margin of the eye; anterior margin of vertex longer than frontal margin of

an eye. Anterior breadth of vertex : synthlipsis :: 12:5. Pronotum a trifle less than twice the length of the head; lateral margins faintly convex and explanate; anterolateral angles slightly embracing the eyes; lateral ledge, as seen from the side, straight, slightly turned down in front and not as long as the rear margin of the eye beneath. Scutellum longer than either pronotum or ridge of hemelytral commissure. Posterior lobe of membrane slightly shorter than anterior lobe. Anterior trochanter of male with minute hook. Mesotrochanter rounded. Male genital capsule as shown on Plate XIV.

Location of Type. In Francis Huntington Snow Entomological Museum, University of Kansas.

Comparative Notes. Distinguished from *N. indica* Linn. by wider synthlipsis and from *N. unifasciata* Guér. by the black scutellum.

Data on Distribution. Known to me only from Mexico, D. F.

Notonecta distinctoidea Hungerford, 1930

(Color Plate II, fig. 6; Plate XIII, fig. 9)

1930. *N. distinctoidea* Hungerford. Bull. Brook. Ento. Soc. XXV, p. 141.

Size. Length, 10.8 mm. to 12 mm.; width of pronotum, 4 mm. to 4.3 mm.

Color. General facies dark. Head, anterior part of pronotum and legs pale yellow to horn. Face, legs and lateral margin of abdominal venter more or less tinged with green. Scutellum black. Hemelytra purplish-black save two short, oblique tan streaks near base of corium and clavus, and tip of membrane, which is pale.

Structural Characteristics. Anterior outline of head viewed from above convex; vertex shorter than its anterior width; margin of vertex less convex than the margin of an eye; anterior breadth of vertex : synthlipsis :: 13:6. Inner margins of the eyes straight and divergent. Pronotum declivant, not quite twice length of head; lateral margins straight and divergent; anterolateral angles slightly embracing the eyes; lateral ledge, as seen from the side, straight and not as long as rear margin of the eye beneath, oblique. Scutellum longer than the pronotum. Hemelytral commissure shorter than scutellum. Posterior lobe of membrane slightly shorter than anterior lobe. Anterior trochanter of male with a very small hook. Mesotrochanters rounded. Penultimate abdominal sternite of female very slightly notched and last one not notched at tip. First pair of gonapophyses of female short. Male genital capsule as shown on Plate XIII.

Location of Type. Holotype in Paris Museum. This species was

described from three males labeled as follows: "Mexique," Coll. Noualhier 1898"; Mexique, Etat de Jalisco, L. Diguet 1900"; Mexico, W. H. Ashm. determined *N. americana* Fab. var. by Kirkaldy '97."

Comparative Notes. See notes under *N. melaena* Kirk. In comparing this species with *N. indicoidea* Hungerford it may be noted that the species is plumper of body (more like *N. melaena* Kirk.) and differs in shape of male genitalia.

Data on Distribution. Known only from type localities.

KEY TO NOTONECTA OF SOUTH AMERICA

1. Keel of fourth abdominal sternite bare, the hairs confined to the sides. . *N. mexicana.** (Colombia, p. 75.)
   Keel of fourth abdominal sternite not bare.................................... (2)
2. Last abdominal sternite of female large and strongly constricted just before the tip, male with digitate prolongation on genital capsule................*N. nigra.* (Brazil?, p. 126.)
   Last abdominal sternite of female normal, male without digitate prolongation on genital capsule .... (3)
3. Pronotum broad in front embracing the eyes, which are flattened, and receding from anterior margin of vertex. Synthlipsis broad, one-half anterior margin of vertex as seen from above. Scutellum plainly broader than long. Male with stout tubercle at angle of front trochanter and a very stout, broad hook as shown on Plate IX, fig. 4.. (4)
   Pronotum and eyes not as above. Scutellum not plainly transverse. Males without stout tubercle at angle of front trochanter and with small hook on its anterior surface .... (5)
4. Length usually under 12 mm...................................*N. ochrothoe.* (Colombia, p. 99.)
   Length usually more than 12 mm..............................*N. colombiana.* (Colombia, p. 128.)
5. Mesotrochanter more or less angulate.. (6)
   Mesotrochanter rounded .... (8)
6. Mesotrochanter distinctly angulate......................*N. unifasciata angulata.* ("S. Amer.," p. 111.)
   Mesotrochanter feebly angulate... (7)
7. Length less than 10 mm......................................*N. bifasciata.* (Argentina, p. 129.)
   Length more than 10 mm.......................................*N. confusa.* ("S. Amer.," p. 130.)
8. Length usually less than 10 mm.. (9)
   Length usually more than 10 mm.. (17)
9. Typical facies dark.. (10)
   Typical facies distinctly black and white.................................... (14)
10. Facies nearly black. Spots on end of corium not conspicuous.................... (11)
    Facies dark but with spots on end of corium distinct or clavus pale.............. (12)
11. Synthlipsis less than one-third width of an eye. Size small. (Max. length, 9 mm.)...*N. pulchra.* (Paraguay, p. 131.)
    Synthlipsis more than one-third width of an eye. Size larger. (Min. length, 9 mm.).......................................*N. polystolisma.* (Brazil, p. 132.)
12. Synthlipsis : width of eye behind : : 5.3 : 9.......................*N. peruviana.* (Peru, p. 134.)

* Other members of this group are keyed out in Key to North and Central America, which see if description does not fit.

Synthlipsis : width of eye behind : : 4 : 9 (about)........................... (13)
13. Synthlipsis : width of eye behind : : 4.1 : 9. (See drawing of male clasper, page 155) ....*N. virescens.*
(Chile, p. 135.)

Synthlipsis : width of eye behind : : 3.9 : 9. (See drawing of male clasper, Plate XII, fig. 3..*N. bicircoidea.*
(Argentina, p. 136.)

14. Hemelytra, viewed from above with two large nearly circular pale spots in the transverse black band. Vertex to synthlipsis : : 5 : 2..............*N. bircirca.*
(Chile, p. 137.)

Hemelytra, viewed from above, with small or transverse tan or pale spots in the transverse black band. Vertex to synthlipsis at least as 3 : 1.................. (15)
15. Vertex to synthlipsis near 3 : 1.. (16)
Vertex to synthlipsis near 4 : 1...................................*N. minuta.*
(Bolivia, p. 138.)

16. Clasper of male genital capsule broad and bifurcate. (See Plate XII, fig. 4) ....*N. sellata.*
(Argentina, p. 139.)

Clasper of male genital capsule not as above. (See Plate XII, fig. 7)..*N. disturbata.*
(Brazil and Paraguay, p. 140.)

17. Color black and white...*N. variabilis.**
(Brazil, p. 141.)
And *N. indica.*
(Colombia, p. 113.)

Color not black and white.. (18)
18. Synthlipsis less than three-fifths of width of eye behind.................*N. fazi.*
(Chile, p. 142.)

Synthlipsis more than three-fifths of width of eye behind.....*N. vereertbruggheni.*
(Argentina, p. 144.)

Notonecta nigra Fieber, 1851

(Color Plate I, fig. 15; Plate XVI, fig. 3)

1851. *N. nigra* Fieber. Rhynchotographieen, p. 473.
1897. *N. nigra* Fieber. Kirkaldy, Trans. Ento. Soc. London for 1897, p. 424.
1904. *N. nigra* Fieber. Kirkaldy, Wien, Ento. Zeit. xxiii, p. 132.
1909. *N. nigra* Fieber. Kirkaldy and Bueno, Proc. Ento. Soc. Wash. x, p. 199.

Size. Length, 16 mm.;† width of thorax 5.5 mm. (female). The male is smaller, being 4.8 mm. across thorax.

Color. Chocolate brown to nearly black. Pronotum, head and limbs shining and also chocolate brown to nearly black. Scutellum and venter black.

Structural Characteristics. As in *N. glauca* L. (See p. 48.)

Location of Types. Three specimens, two females and one male, in Vienna Museum, and one specimen, a female, in Paris Museum.

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* See discussion under these two species.

† NOTES ON FIEBER'S MEASUREMENTS: Doctor Fieber gave the length of his Notonecta species in "linien." Since several different units called lines have been employed, I wrote to my friend, Doctor Walther Horn, concerning the problem. With his usual kindness he promptly informed me that: "We have had in the past time in Europe almost as many different kinds of 'linien' as small states. Sometimes a 'linie' was one-tenth, sometimes one-twelfth of an inch. In the following I give you three kinds: Paris 'linie,' 2.2558 mm.; Rheinprovinz linie, 2.179 mm.; English line, 2.116 mm. There have been many other kinds. For example, there is before me a measuring instrument where 12 "linien" = 27 cm." Fortunately, I have studied Fieber's *N. nigra* types in the Vienna museum. They measure 16 mm. in length. Since Doctor Fieber gives "7⅓ linien" as the length of this species, it is easy to figure that he employed the Rheinprovinz linie, which equals 2.179 mm.

One of the Vienna females lacks distal half of abdomen, and the male has lost the hind legs and the tibia of one front leg. The Vienna specimens are labeled "Brasilien" and the Paris specimen "Brèsil." I have compared the labels side by side; the paper is the same in texture and of the same width. The "Brazilien" label is longer. The handwriting and the ink look identically the same to me. The pins are, however, quite different, but both specimens show that they have been repinned. The Paris specimen bears also the label "Museum Paris, Coll. Noualhier 1898." It is even nearer black than the Vienna specimens and is labeled "type." I would give it cotype standing, and have labeled the Vienna specimens with red cotype labels. Fieber wrote "Aus Brasilien (kais. kön Hofnat. Cabinet in Wien; gesammelt von Schott).

Comparative Notes. This species is a puzzle to me. I can find no structural characteristics to distinguish it from *N. glauca* Linn. of Europe. The genital capsules of the males are alike and the female genitalia are alike. The specimens of *N. nigra* Fieb. are larger than the average *N glauca* Linn. and have a little different shape. The unusual color of *N. nigra* Fieb. certainly gives it a different facies. At times I have been convinced that these four specimens might be only stained specimens of *N. glauca* Linn., labeled "Brèsil" and "Brasilien" by some unscrupulous dealer. I have seen Notonecta collected from acrid coffee-colored waters of some bogland pool that were nearly as dark as *N. nigra* Fieb. For example, in the Museum of Paris there is a series of specimens labeled "Takersan," "Museum Paris, Algérie, P. Lesne 6-97," determined as *N. glauca* by Kirkaldy and more recently *N. maculata*." One of these has the venter covered with bits of wood fiber, as if taken in a pool of coffee-colored water, and is nearly as black as the cotypes in Vienna. There are other specimens that have the black legs and are but slightly lighter in color, and still others that are of typical *N. maculata* color. Even the darkest specimens of this series, however, have the orange band on the abdominal dorsum. I recall also a female specimen labeled "Soeul, Korea," in the Hungarian Museum at Budapest. This specimen is light chocolate in color. The venter is covered with bits of wood, as if the specimen had been collected in amber-colored bog waters. The scutellum is black; the anterior margin of hemelytra shows faintly the darker maculations that are so characteristic of *N. glauca* Linn. Compared with *N. canariensis* Kirkaldy, *N. nigra* Fieb. is a more slender species; the head is smaller and the limbs very plainly more slender. Compared with

N. v. viridis Delcourt, it does not have the anterior lateral angles of the pronotum embracing the eyes, and has longer and more slender front and middle legs.

There will continue to be some doubt in my mind about the authenticity of the label "Brazil" until some further evidence is available. I have many South American Notonecta from various places in Brazil, but no species even akin to this *N. nigra* Fieber have been taken in South America in modern times.

In the museum at Oxford, England, there are two insects (a male and a female) that look like *N. obliqua* Gallén and bear a tiny green square and a label, "Miers coll.; Presented 1880 by J. W. Miers." Professor Poulton says most, if not all, of Miers' insects came from South America.

While there is still much uncertainty about *N. nigra* Fieber, I do not wish to take the responsibility of denying the existence of this species in South America, and am sure that if further material becomes available it will be possible to find in a longer series the proper position of this species. Every South American collector should be on the alert for this species.

Notonecta colombiana new species.

Size. Length, 12 mm. to 12.6 mm.; width of pronotum, 4.5 mm.

Color. No doubt a bichromatic species, but only the dark form known to me. The scutellum is black. The hemelytra are brown and black with a luteous streak along the claval suture and a luteous transverse spot at end of basal third of corium. Lower half of propleuræ, prosternum, mesoternum and spots on abdominal venter black. Face, limbs and connexivum may be yellowish or suffused with green.

Structural Characteristics. Anterior outline of head viewed from above quite convex; vertex longer or subequal to its anterior width; margin of vertex more convex than margin of the eye; anterior breadth of vertex : synthlipsis : : 17:12. Pronotum steeply declivant as viewed from the side. Pronotum twice length of the head; lateral margins somewhat divergent and straight; anterior angles acute and embracing the eyes; lateral ledge as seen from the side nearly straight, as long as the rear margin of the eye below it, and nearly horizontal. Scutellum about as long as pronotum. Anterior lobe of membrane a little longer than posterior lobe. Anterior trochanter of male with the stout hook and protuberance characteristic of the *N. shooteri* group. Male genital capsule much as in *N. melaena* Kirk.

Location of Type. Holotype, allotype and two paratypes in the Zoölogical Museum at Berlin; two paratypes in Francis Huntington Snow Entomological Museum of University of Kansas. The above labeled "Bogata 8000?, Kalte Region, Bobisch L." Hamburg Museum has two paratypes labeled "Bogata, Dr. O. Bürger leg. III, 1897, Vend. 1, I, 1898." In the Vienna Museum there is one labeled "Bogata, Coll. Signoret," and is marked "*N. rugosa* Fieb."

Comparative Notes. Mistaken for *N. shooteri* Uhler, from which they differ by the shape of male genital capsule, by the straighter margins of the pronotum and more declivant pronotum. It is a larger species than *N. melaena* Kirkaldy, with more rounded head and luteous stripe on claval commissure.

Data on Distribution: Colombia, South America: Bogata 8000', Bobisch L. (Berlin Mus.); Bogata, Dr. O. Bürger, leg. III, 1897. Vend. 1, I, 1898, Hamburg Mus.; Bogata coll. Signoret (labeled *rugosa* Fieb.).

Notonecta bifasciata Guérin, 1844

(Plate XII, fig. 1)

1844. *N. bifasciata* Guérin-Méneville. Icon. du Regne Anim. Ins., III, p. 354.

1851. *N. bifasciata* Guérin. Fieber, Rhynchotgraphieen (Abh. Böhm. Ges. Wissensch. Prag V, 7, p. 480). (Known to Fieber only by desc.)

1853. *N. bifasciata* Guérin. Herrich-Schäffer, Die Wanzenartigen Insecten IX, p. 136 (in Index).

1879. *N. bifasciata* Guérin. Berg, Hemiptera Argentina . . ., p. 197 of reprint. (Under *N. variabilis* Fieb. in error.)

1897. *N. bifasciata* Guérin. Kirkaldy, Trans. Ento. Soc. London, 1897, p. 413. (Kirkaldy saw the type.)

1899. *N. bifasciata* Guérin. Kirkaldy, Boll. Mus. Torino, xiv, No. 347, p. 2. (Only in part.)

1904. *N. bifasciata* Guérin. Kirkaldy, Wien, Ento. Zeit. xxiii, pp. 95-132. (Kirkaldy thought only a var. of *N. undulata* Say, but was in error.)

1909. *N. bifasciata* Guérin. Kirkaldy and Bueno. Catalogue . . .Proc. Ento. Soc. Washington, x, p. 198. (Only in part.)

1926. *N. bifasciata* Guérin. Hungerford, Psyche xxxiii, pp. 12 and 15. (My error; not this species.)

1930. *N. bifasciata* Guérin. Hungerford, Bull. Brooklyn Ento. Soc., xxv, p. 140. (Corrects error of 1926.)

Size. Given by Guérin as 8.5 mm. long and 3 mm. wide. According to my measure, the type is 9.3 mm. long.

Color. I have seen the type, which is a male, and give the following descriptive information: The general facies dark, the scutellum black; hemelytra dark except a pale stripe on basal two-thirds of clavus, the inner margin against the scutellum being brown throughout; against the clavocorial suture there is a triangular pale patch on the corium; at distal end of embolium (on the suture) there is a transverse orange spot and above it a larger one irregular in shape;

tip of membrane pale, hemelytra (the dark part particularly) covered with silvery, narrowly spatulate hairs.

Structural Characteristics. Anterior margin of vertex : synthlipsis :: 11:4; the width of an eye at its base equals the width of the anterior margin of the vertex. The anterior trochanter of the male has the little hook, as in other small South American species, such as *N. bicirca* Hungerford, for example. The mesotrochanter is not angulate, but not rounded as in some other species. The male genital capsule is shown on Plate XII, figure 1.

Location of Type. There is a specimen in the Paris Museum labeled "type," and from the top down the labels read: 1st, "Type"; 2d, "Museum Paris, Maldonado Coll. Guér.-Menev. ex coll. A. Sálle 1897" (printed); 3d, "Notonecta bifasciata Guér. Ic. R. A. Platta (type) Maldonade" (written); 4th, "Notonecta polystolisma Fieb., p. 53, Maldonado bifasciata Guér. Ic. R. A. (type)"; 5th, "*Notonecta bifasciata* Guér. det Kirkaldy 1897." Kirkaldy quotes these on page 413 of his "Revision." The type is a male and appears to have been broken into two or three parts and glued together. One hemelytron is in two pieces and glued to the side of the body, and the pronotum sometime has been parted from the after body.

Comparative Notes. I was surprised to find that this is not the species I named *N. bifasciata* in my paper of 1926, where I figured the genital capsule of what I thought to be Guérin's species. The type has a male clasper more like my *N. pulchra,* but it is not the same species. *N. pulchra* Hungerford is a smaller species with longer head and narrower synthlipsis. On the other hand, it is a smaller species than my *N. bicirca* or *N. bicircoidea.* Of course, it is not what I named *N. polystolisma* var. *spatulata.* While the shape of the male genital capsule resembles somewhat my *N. disturbata,* a comparison of the species side by side shows them to be distinct. *N. disturbata* Hungerford has a longer head and a narrower synthlipsis. Indeed, it proved to be a species I had never seen.

Data on Distribution. Known to me only by the type. I cannot accept the distribution records of former workers, who most obviously have confused the species. Maldonado is in Uruguay, S. A.

Notonecta confusa Hungerford, 1930

(Color Plate II, fig. 4; Plate XIII, fig. 7)

1930. *N. confusa* Hungerford. Bull. Brooklyn Ento. Soc., xxv, p. 140.

Referring to this species, also:

1926. *N. species?* Hungerford. Psyche, xxxiii, pl. 2, fig. 6.

Size. Length, 12 mm.; width of thorax, 4 mm.

Color. The color of the solitary type specimen is pale yellow throughout. The typical color is probably black and white as in *N. undulata* Say.

Structural Characteristics. Size and general appearance might confuse this species with *N. undulata* Say, from which it differs in having the mesotrochanter feebly angulate and the male genital clasper with broader branches, as shown on Plate XIII.

Location of Type. Described from a single male specimen from "S. Amer." type in the P. R. Uhler collection in the U. S. National Museum, Washington, D. C.

Comparative Notes. Until a series of specimens, including both sexes, is found, it is impossible to offer any further comparisons.

Data on Distribution. Beside the type, I have a specimen labeled "Cuba" which belongs to this species.

Notonecta pulchra Hungerford, 1926

(Color Plate I, fig. 10; Plate XII, fig. 8)

1926. *N. pulchra* Hungerford. Psyche XXXIII, p. 14, Pl. II, fig. 3.

Size. Length, 7.5 mm. to 9 mm.; width of pronotum, 2.18 mm. to 3.1 mm.

Color. General facies dark. Scutellum entirely black or marked with a tan spot on each lateral margin. Hemelytra black save two pale spots at base of hemelytra and an orange irregular transverse band at end of corium. Silvery hairs on hemelytra. When typically colored, a beautiful little species.

Structural Characteristics. Anterior outline of head viewed from above nearly flattened; vertex as long as anterior width; margin of vertex less convex than anterior margin of an eye; anterior breadth of vertex : synthlipsis : : 11:3; synthlipsis less than one-third the rear margin of an eye. Pronotum less than one and one-half times as long as head; lateral margins straight and quite divergent; antero-lateral angles not embracing the eyes; lateral ledge, as seen from the side, curved, oblique and shorter than rear margin of eye beneath. Scutellum a little longer than pronotum. Membranal lobes about equal. Anterior trochanter of male with hook. Mesotrochanter rounded. Penultimate abdominal sternite of female notched. Last one not elongate, notched at tip. Male genital capsule as shown on Plate XII.

Location of Types. Holotype, allotype and some paratypes in Francis Huntington Snow Entomological Museum, others in U. S. N. M. at Washington, D. C.

Comparative Notes. The typical color of this species sets it apart from the others of its size. The plump capsule of the male with its broader clasper separates it from *N. disturbata* Hungerford and *N. bifasciata* Guérin.

Data on Distribution. Paraguay: Villarica, Dec. 16, 1927, F. Schade; Villarica, Estero Granda, Nov. 1, 1924, F. Schade; Villarica, Sept. 16, 1923, F. Schade; Villarica, March 26, 1924, F. Schade; Caraveni, L. Montis, Oct. 30, 1924, F. Schade; Villarica, Jan. 19, 1926, F. Schade.

Notonecta polystolisma Fieber, 1851

(Color Plate I, fig. 11; Pl. XII, fig. 2)

1851. *N. polystolisma* Fieber. Rhynchotographieen, pp. 477-478.
1926. *N. polystolisma* Fieber. Hungerford, Psyche xxxiii, p. 12.
1928. *N. polystolisma* Fieber. Jaczewski, Annales Musei Zoölogici Polonici vii, p. 121.

Referring to this species, also:

1851. *N. polystolisma* var. *guttata* Fieber. Rhynchotographieen, p. 478.
1851. *N. polystolisma* var. *bipunctata* Fieber. Rhynchotographieen, p. 478.
1851. *N. polystolisma* var. *fasciata* Fieber. Rhynchotographieen, p. 478.
1851. *N. polystolisma* var. *immaculata* Fieber. Rhynchotographieen, p. 478.
1897. *N. bifasciata* Kirkaldy. Trans. Ent. Soc. London for 1897, p. 413. (As syn. in error.)
1904. *N. bifasciata* Kirkaldy. Wien. Ent. Zeit., xxiii, p. 132. (As syn. in error.)
1909. *N. bifusciata* Kirkaldy & Bueno. Proc. Ent. Soc. Wash. x, p. 198. (As syn. in error.)
1926. *N. polystolisma* var. *spatulata* Hungerford. Psyche xxxiii, p. 12.

Size. Length, 9 mm. to 9.6 mm.; width of pronotum, 3.1 mm. to 3.45 mm.

Color. General facies dark. Anterior half of pronotum, propleura, head and legs from horn to brownish yellow often tinged with green. Venter brown to black except metaxyphus and connexivum, which are usually colored like the legs. Scutellum black except in teneral specimens. Hemelytra black or blue black with oblique bifurcate tan streak along basal half of claval commissure, and either two spots or transverse band across corium at tip of clavus. Tip of membrane usually pale.

Structural Characteristics. Anterior outline of head, viewed from above, only slightly convex; vertex slightly shorter than anterior width and less convex than anterior margin of the eye; anterior breadth of vertex : synthlipsis :: 3:1 (sometimes 10:3); the synthlipsis much less than half the rear margin of the eye. Pronotum less than one and one-half times as long as the head; lateral margins straight and divergent; anterolateral angles not embracing the eyes; lateral ledge as seen from the side faintly sigmoid and decidedly

oblique, shorter than the rear margin of the eye beneath. Scutellum longer than the pronotum. Membranal lobes subequal. Anterior trochanters of male with hook. Mesotrochanters rounded. Penultimate abdominal sternite of female notched, last one rather elongate and roundly notched at tip. Female gonapophyses of moderate length. Last abdominal sternite of male rather large and constricted before the tip. Male genital capsule large and as shown on Plate XII.

Location of Type. Fieber described five varieties under this species, one of which is *N. sellata* and a very distinct species. The other four are from Brazil and appear to be stages of pigmentation of a single species. I named a variety "*spatulata*," but now suppress it, as I consider the dark form as really the usual color of the species. There are no specimens in the Berlin Museum that I can mark with certainty as types. Under the name *Notonecta polystolisma* Fieb. there is a mixed lot of five specimens, three are *N. indica* Linn. and other two labeled "Cat. No. 3631, Brazilien, Sellow" are what I consider correctly named. There are some unnamed Notonecta in Berlin Museum that belong under this name: One pale specimen labeled "3633 Brasil, Sellow," and another "3634 Brasil, Sellow." The latter is a male with pale scutellum and hemelytra. The female "3633" is partly pigmented. It has a dirty brownish to black median area on scutellum with an uneven paler stripe along lateral margins, the clavus and upper part of corium are pale, a thin brown streak on clavus bordering a brown streak between corium and embolium from base to middle of corium where it widens into a patch of brown covering distal half of embolium and corium but not reaching up to claval margin. Some brown on base of membrane. There are some dark forms labeled as follows: "Lages, Brasilien, St. Catharina, Fruhstorfer"; Brasilien, Osten Sacken; Allegrette 3635; 8014 labeled "pallipes, Fabr.," "Brasil Coll. Germ."

Comparative Notes. A little larger than most of the other small typically South America species. The male genital capsule is large and distinctive.

Biological Notes. Doctor Jaczewski, who collected this species in the state of Paraná, Brazil, S. A., found it in ponds and pools in open country and in forests. Some of the pools were formed in the course of small streams. Adults were taken from January to June and nymphs in March, April and June.

Data on Distribution. In addition to the data published by Doc-

tor Jaczewski in Notonectidæ from the state of Paraná, 1928, I can add the following from the collection before me:

BRAZIL: Ypirango, S. Paulo, R. Spitz; Itapuaqueaetuba, Via Poa, EFCB Sao Paulo, E. D. Townsend; Sao Paulo, Aug. 7, 1927, E. D. Townsend (and nymphs); Estado de Sao Paulo, Nov., 1928, E. D. Townsend.

Notonecta peruviana new species

Size. Length, 9.3 mm. to 10.3 mm.; width of prothorax, 3.45 mm.

Color. General facies dark when fully pigmented. Scutellum black. Hemelytra dark with broad oblique streak, tan or horn along base of clavocorial line; oblique orange line on caudal margin of embolium and an obscure orange spot on corium above; membrane mostly brown.

Structural Characteristics. Anterior outline of head somewhat rounded, slightly more convex in female than in male; vertex shorter than its anterior width; margin of vertex less convex than frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 15:8. Vertex a little wider in the females. Synthlipsis : width of the eye behind :: 5.3:9. Pronotum trifle less than twice length of the head; lateral margins straight, moderately divergent; antero-lateral angles slightly embracing the eyes; lateral ledge as seen from the side curved and oblique, shorter than rear margin of the eye beneath. Scutellum and pronotum subequal in length. Ridge of hemelytral commissure as long as scutellum. Lobes of membrane of hemelytra equal in length. Anterior trochanter of male rough but hook obscure. Mesotrochanters rounded. Penultimate abdominal sternite of female with deep but narrow notch, last one faintly or not notched. First pair of female gonapophyses short. Male genital capsule as shown on page 155.

Location of Type. Holotype and allotype in Hungarian Museum at Budapest. Paratype in Francis Huntington Snow Entomological Museum, University of Kansas.

Comparative Notes. Separated from *N. virescens* Blanchard and *N. bicircoidea* Hungerford by its wider synthlipsis and by shape of male genital claspers.

Data on Distribution. Known only by the male and two females labeled "Peru, Lauramarca."

Notonecta virescens Blanchard, 1852

(Color Plate II, fig. 11)

1852. *N. virescens* Blanchard, *in* Gay's Chile, Zool., viii, p. 233. Atlas Zoöl. Ins. Hemipt., Pl. II, p. 16.

1863. *N. virescens* Blanchard? Signoret, Revision des Hemipteres du Chile. (Seance du 22 Avril 1863.) (Doubtful—gives length 10 mm.)

1926. *N. virescens* Blanchard. Hungerford, Psyche xxxiii, p. 11.

1930. *N. virescens* Blanchard. Hungerford, Bull. Brooklyn Ent. Soc., xxv, p. 139.

Referring to this species, also:

1897. *N. undulata* var. *virescens* Kirkaldy. Trans. Ent. Soc. London for 1897, p. 411.

1904. *N. undulata* var. *virescens* Kirkaldy. Wien. Ent. Zeit., xxiii, pp. 95 and 132.

1909. *N. undulata* var. *virescens* Kirkaldy and Bueno. Proc. Ent. Soc. Wash., x, p. 199.

Size. Length, 8.7 mm. to 9.3 mm.; width of pronotum, 3 mm. to 3.4 mm.

Color. The type is luteous with hemelytra incompletely marked with brown. The upper pale spot of corium large and not closed, silver, narrowly spatulate hairs on hemelytra. The second specimen is entirely luteous. I have before me three pigmented specimens that must be this species. These have black scutellum with brown stripe on either margin and another before the tip. Clavus is horn except at hemelytral commissure where it is smoky brown, two pale stripes near base of corium separated by smoky, brown streak. Distal half of corium and basal half of membrane black embracing a small tan spot on embolial suture and a large irregular one above it. Colored more like *N. bicircoidea* Hungerford than like *N. bircirca* Hungerford.

Structural Characteristics. Anterior outline of head, viewed from above, somewhat convex; vertex shorter than its anterior width; anterior breadth of vertex : synthlipsis :: 5:2; anterior breadth of vertex a little greater than the rear margin of an eye; the synthlipsis a little more than two-fifths the rear margin of an eye. Pronotum about one and five-sevenths as long as the head; lateral margins in the type less divergent than in *N. bicirca* Hungerford; lateral margins straight; anterolateral angles slightly embracing the eyes; lateral ledge, as seen from the side, curved and shorter than rear margin of the eye beneath. Scutellum a little longer than the pronotum. Membranal lobes subequal. Anterior trochanter of male with hook. Mesotrochanter rounded. Penultimate abdominal segment notched and last one shallowly and roundly notched. Male genital capsule as shown in Text Figure on page 155.

Location of Type. In Paris Museum. The type is a dermestid eaten female, labeled "Museum Paris. Chili, Gay 15 = 43." The

head and prothorax are gone. Only one leg left and this is the right middle leg. The hemelytra are incompletely marked with brown as stated above. A second specimen is entirely pale. There are two specimens labeled "Museum Paris, Chili, Coll. G. Fallou 259-95," but this has an angulate trochanter, and the label must be wrong, for this is *N. lunata* Hungerford. There are two other specimens labeled "Museum Paris, Chili, Coll. G. Fallou 259-95" det. *N. virescens* by Fallou and *N. undulata* var. *virescens* by Kirkaldy. These are males.

Comparative Notes. I have compared my own types with this species and find it to be different. The male clasper is more pointed behind than in either *N. bicirca* or *N. bicircoidea.*

Data on Distribution. From Chile, S. A. There are therefore two very closely related little species from Chile and another across the divide in Argentina.

Notonecta bircircoidea Hungerford, 1928

(Color Plate II, fig. 8; Plate XII, fig. 3.)

1928. *N. bircircoidea* Hungerford. Annals Ent. Soc. Am. xxi, p. 120.

Size. Length, 8.8 mm. to 9.6. mm.; width of pronotum, 3.15 mm. to 3.3 mm.

Color. General facies quite like *N. bicirca* Hungerford but darker. The elongate yellow spot on lateral margins of scutellum, which is present in *N. bicirca* is nearly always absent or tan in this species. Hemelytral commissure and tip of clavus black.

Structural Characteristics. The head slightly less prominent than in *N. bicirca* and the anterior margin of vertex a little more rounded; vertex shorter than its anterior width; anterior breadth of vertex : synthlipsis :: 5:1.9. Anterior breadth of vertex greater than rear margin of an eye. Synthlipsis less than half the rear margin of an eye. Pronotum less than twice as long as the head; lateral margins straight, moderately divergent; anterolateral angles nearly normal, slightly embracing the eyes; lateral ledge, as seen from the side, curved, oblique and shorter than rear margin of the eye beneath. Scutellum a little longer than the pronotum. Membranal lobes subequal. Anterior trochanters of male with hook. Mesotrochanters rounded. Penultimate abdominal sternite of female notched, last one broadly and shallowly notched. Male genital capsule as shown on Plate XII. It is relatively larger than in *N. bicirca* Hungerford.

Location of Types. In Francis Huntington Snow Entomological

Museum, University of Kansas. Described from fourteen specimens, four males and ten females, taken by Mr. Vereertbrugghen in Rio Negro Territory, Argentina.

Comparative Notes. Head slightly less prominent than in *N. bircirca,* color pattern difference as shown on Plates I and II. Male capsule relatively larger and clasper broader, with the front and rear curves differently located.

Data on Distribution. Known to me only by the types.

Notonecta bicirca Hungerford

(Color Plate I, fig. 16; Plate XII, fig. 5.)

1926. *N. bicirca* Hungerford. Psyche xxxiii, p. 12, Pl. 2, fig. 1.
1928. *N. bicirca* Hungerford. Ann. Ento. Soc. Amer., xxi, p. 120.

Size. Length, 8.4 mm. to 9.3 mm.; width of pronotum, 3 mm. to 3.3 mm.

Color. General facies spotted, white with scutellum and two circles on hemelytra black. Closer inspection reveals posterior half of pronotum darkened by black thorax beneath, an elongate yellow spot on lateral margins of scutellum; hemelytra yellowish white covered with silvery hairs and with the following typical maculations: Submarginal band of black on base of corium; distal end of clavus black; broad transverse black band traversing distal third of corium and base of membrane and embracing a small orange-yellow spot at end of embolium and entirely surrounding a much larger nearly circular spot above. The general effect produced is that of two black circles surrounding orange-yellow spots upon the insects, the lateral orange-yellow spots upon the margins of hemelytra and opening upon the embolial sutures being unnoticed.

Structural Characteristics. Anterior outline of head slightly convex, more so in male than in female; vertex longer than its anterior width in male, subequal in female; margin of vertex less convex than frontal margin of the eye; anterior breadth of vertex : synthlipsis :: 5:2; anterior breadth of vertex greater than rear margin of an eye; synthlipsis slightly less than twice the rear margin of an eye. Pronotum less than twice as long as the head; lateral margins nearly straight and moderately divergent; anterolateral angles about normal; lateral ledge as seen from the side, curved, oblique and shorter than the rear margin of the eye beneath. Scutellum a little longer than the pronotum. Membranal lobes subequal. Anterior trochanter of male with hook. Mesotrochanters rounded. Penultimate abdominal sternite of female notched and last one broadly

and shallowly notched. Female gonapophyses short. Male genital capsule as shown on Plate XII.

Location of Types. In Francis Huntington Snow Entomological Museum, University of Kansas. Some paratypes in U. S. N. Museum, Washington, D. C. Described from 50 specimens from Chile, S. A. Some from Santiago and others from Termas Cauquences, Dec. 15, 1922, by Alfredo Faz.

Comparative Notes. The characteristically spotted appearance of this species is distinctive. While now and then a *N. sellata* Fieb. specimen may have same general color appearance, Fieber's species has narrower synthlipsis and entirely different male clasper. The closest relatives are *N. virescens* Blanchard and *N. bircircoidea* Hungerford. It requires an examination of the claspers of the male to distinguish precisely these three species when the typical coloring is lacking. Both of the latter species are usually more deeply pigmented.

Data on Distribution. Besides the type series I have the following from Chile: Limache, Nov. 12, 14, 15, 1923, A. Faz.

Notonecta minuta Hungerford, 1926

(Color Plate I, fig. 9; Plate XII, fig. 6)

1926. *N. minuta* Hungerford. Psyche xxxiii, p. 14, pl. II, fig. 7.

Size. Length, 7.2 mm.; width of pronotum, 2 mm.

Color. Head, pronotum, legs and basal third of hemelytra yellow. Scutellum and distal two-thirds of hemelytra black with tips of membrane pale. In the broad, black area across the hemelytron are two small, irregular orange spots of nearly equal size. On one of the three specimens there are ill-defined yellowish spots near the base and at the tip of the scutellum.

Structural Characteristics. Anterior outline of head, viewed from above, but slightly convex; vertex longer than its anterior width; margin of vertex less convex than anterior margin of the eye; anterior breadth of vertex : synthlipsis :: 9:2.1; width of eye at base equal to width of vertex; synthlipsis less than a third the rear margin of an eye. Pronotum but little longer than the head; lateral margins divergent and straight; anterolateral angles acute, slightly embracing the eyes; lateral ledge nearly straight, shorter than the rear margin of the eye beneath. Lobes of membrane subequal. Anterior trochanter of male with hook. Mesotrochanters rounded. Male genital capsule as shown on Plate XII.

Location of Types. Described from specimens in the Carnegie

Museum bearing the label "Prov. del Sara Bolivia 450 m. J. Steinbach." One paratype in Francis Huntington Snow Entomological Museum, University of Kansas.

Comparative Notes. The smallest Notonecta known to me.

Data on Distribution. Known only from the types.

Notonecta sellata Fieber, 1851

(Color Plate I, fig. 14; Plate XII, fig. 4.)

1851. *N. Polystolisma* var. *sellata* Fieber. Rhynchotographieen, Böhm Gesell. der Wissensch. Abh. v, 7, p. 478.

1930. *N. sellata* Fieber. Hungerford, Bull. Brooklyn Ento. Soc., xxv, p. 140.

Referring to this species, also:

1861. *N. variabilis* Burmeister. Reise durch die Plata-Staaten I, p. 492 (1861) (probably in part). Says he found it in Montevideo, but not close to Paraná.

1879. *N. polystolisma* Berg. Hemiptera Argentina, p. 198 (reprint from Ann. S. Cient. Argent., viii, p. 75).

1897. *N. variabilis* Kirkaldy. Trans. Ento. Soc. London, 1897, p. 414 (in part).

1904. *N. variabilis* Kirkaldy. Wien. Ento. Zeit, xxiii, p. 95. (Which he considered a var. of *N. undulata* Say, in error).

1909. *N. undulata* Kirkaldy and Bueno. Proc. Ento. Soc. Washington, x, p. 199 (in part).

1926. *N. bifasciata* Hungerford. Psyche, xxxiii, p. 12, plate II, fig. 5.

Size. Length, 8.7 mm. to 9.6 mm.; width of pronotum, 2.8 mm. to 3.2 mm.

Color. Typical color white, with transverse black band across clavus, in which are two tan spots, and with black scutellum margined laterally by short pale stripe. The species may vary from pale to strongly pigmented, as in *N. undulata* Say, for example. Even the darkest forms do not have the scutellum solid black, and all but the teneral forms have abdominal dorsum dark and metathorax black.

Structural Characteristics. Anterior margin of head, viewed from above, only slightly convex; vertex longer than anterior width and less convex than anterior margin of an eye. Anterior breadth of vertex : synthlipsis :: 3:1; the synthlipsis much less than half the rear margin of the eye. Pronotum about one and one-half times as long as head: lateral margins straight in females, slightly concave in males and divergent; anterolateral angles not embracing the eyes; lateral ledge as seen from the side slightly curved, oblique, and shorter than rear margin of eye beneath. Scutellum longer than pronotum. Membranal lobes equal. Anterior trochanters of male with hook. Mesotrochanter rounded. Penultimate abdominal sternite of female notched, last one not elongate, notched at tip. Female gonapophyses (first pair) short. Last abdominal sternite of

male normal in size and constricted before the tip. Male genital capsule as shown on Plate XII.

Location of Type. There is a specimen in Berlin Museum labeled "3637 La Platta, Besoke" "Sellata, Germ." This fits description of *N. polystolisma* var. *sellata* Fieber exactly, but bears another label, *N. variabilis* var. *sellata* Germ. If it is not Fieber's type it is certainly Fieber's "*sellata*." Fieber's type was designated "*Notonecta sellata* Germ. Coll. Buenos Ayres. (Mus. Berol. Hal.) The commonest species about "Buenos Ayres" is this species.

Comparative Notes. The characteristic clasper of the male genital capsule readily separates this species from all other species.

Data on Distribution. I have before me the following:

ARGENTINA: Buenos Aires, Mercides, IV, 12, 1923 R. Hosford; Buenos Aires, Mercides, XI, 19, 1923, R. Hosford; Buenos Aires, Jan. 18, 1904 (U. S. N. M.); Lopez, Mendoza, S. A., C. S. Reed; Alrededores de La Rioja, M. S. Pennington; Buenos Aires, Republique Argentine, J. Künchel 1899, XI, 1897. (Paris Museum); Rep. Argentine Rosario, J. Claine, 1898 (Paris Mus.) Entre Rios. (Paris Mus.); Montevideo, Coll. Noualhier, 1898 (Paris Mus.); Cosquin, Arg. S. A., March 8, 1921, J. C. Bradley (Cornell Univ.); Argentina, S. A. 1925; Argentina, La Granja, Altagracia, Cordoba, 1923, A. Bruch.

PARAGUAY: Villarica, Loma, Aug. 8, 1924, F. Schade; Molinasque, June, 1928, F. Schade.

BRAZIL: Alto Paraná, Aug. 29, 1929, F. Schade; Manacapuru, Manaos, Amaz., March, 1928, S. M. Klages.

BOLIVIA: Dr. A. Barelli (bears two det. labels, 1st "*N. bifasciata* Guer. det. Kirkaldy, 97"; 2d "*N. bifasciata* = polystolisma det. Kirkaldy).

Notonecta disturbata Hungerford, 1926

(Color Plate I, fig. 13; Plate XII, fig. 7.)

1926. *N. disturbata* Hungerford. Psyche, xxxiii, p. 13, Pl. II, fig. 2.

Size. Length, 8 mm. to 8.4 mm.; width of pronotum, 2.8 mm. to 2.9 mm.

Color. From luteous to black and white. The pale ones entirely light, the pigmented ones having a black scutellum with brown stripe on each lateral margin. The hemelytra white with distal end of clavus brownish black and distal half of corium and basal two-thirds of membrane black.

Structural Characteristics. Anterior outline of head somewhat convex; vertex longer than its anterior width; vertex less convex than margin of the eye; anterior breadth of vertex : synthlipsis :: 10:2.7; synthlipsis less than one-third rear margin of an eye, which is equal to or less than width of anterior margin of vertex. Pronotum not more than a third longer than the head; lateral margins

straight and divergent, anterolateral angles normal; lateral ledge, as seen from the side, curved, oblique and shorter than rear margin of an eye beneath. Scutellum a little longer than the pronotum. Membranal lobes equal. Anterior trochanter of male with hook. Mesotrochanters rounded. Penultimate abdominal sternite with narrow, deep notch and last one shallowly notched. Male genital capsule as shown on Plate XII.

Location of Type. Sao Paulo Museum, paratype in Francis Huntington Snow Entomological Museum. Three specimens from Campo, Bello Staat, Rio de Janeiro, IV, 1906.

Comparative Notes. The unusual shape of the male genital capsule distinguishes this species.

Data on Distribution. I have before me the following series of this species. Villarica, Paraguay, Dec. 6, 1923, Dec. 15, 1922, Dec. 5, 1923, F. Schade; Natterer, Brasilien (Det. by Kirkaldy as *N. variabilis* Fieb.).

Notonecta variabilis Fieber, 1851

1851. *N. variabilis* Fieber. Rhynchotographieen Abh. böhm Ges. Wiss., v. 7, p. 477.

Referring to this species, also: Fieber described four varieties of this species. Three from Brazil and one from Baltimore. His South American varieties were named *scutellaris, dorsalis* and *unicolor* and were not worthy of varietal names. His *maculata* from Baltimore is another species, now *N. lunata* Hungerford.

Size. Fieber gives the size as 4 4/6 linien, which would be 10.17 mm.

Color. Variable. Some specimens are yellowish-white with face, limbs and connexivum more or less greenish; scutellum in such cases uniformly yellowish-white or more or less suffused with brown. Other specimens may have a broad, black band covering all but the tip of the membrane, across the caudal third of the hemelytra; in such specimens the scutellum may be entirely black, black with lateral margins flavous, or black with from one to three flavous spots—one at the tip and one at the base on either side—or in the case of a single spot, only the tip pale. It is probable that still darker forms occur as in *Notonecta indica* Linn., to which this species is very closely related, if not identical with it.

Structural Characteristics. Almost identical with those of *Notonecta indica* Linn. even to the clasper of the male genital capsule. Fieber says that the front half of the pronotum is finely cross-

wrinkled, which character does distinguish these specimens from *N. polystolism* Fieber.

Location of Type. Doctor Kirkaldy could not locate the type. I have examined the collections at Berlin, Vienna and Halle, where Fieber said his specimens were located, and did not find types. In the Berlin Museum there is a pair of specimens labeled "Cat. No. 3632" "Brasilien, Sallow." One of these is a male and resembles *N. indica* Linn. (= *N. howardii* Bueno) in the shape of the clasper of the male, in size and color, rounded mesotrochanter, etc. It has the broad, black vitta across the wings. The scutellum is yellow, except tiny brown spots at base and in the middle. There is a brown line along margin of clavus where it meets the scutellum, a brown streak along front wing margin extending from base of wing to the large black transverse vitta and an indefinite sooty patch on corium. The female has a black scutellum except a yellow spot on each anterior corner and at the tip. It has the broad, black vitta across the hemelytra as in the male. It might well have served for Fieber's description of *N. variabilis* var. *scutellaris*. Since Doctor Fieber said this variety came "Aus Brasilien, Portorico (Mus. Vienn. et Berol.)" and since the above specimens are exceedingly close to, if not identical with, the species common in the islands, I hereby propose to consider these two specimens as plesiotypes of *N. variabilis* Fieber.

Data on Distribution. I have chosen to retain *N. variabilis* Fieb. as a name for the specimens that come from Brazil, in spite of their very close resemblance to the specimens found in Porto Rico which belong to *N. indica* Linn. This I believe to be the safest policy until we find more Brasilian specimens to study or other specimens from intervening territory.

Notonecta fazi Hungerford, 1930

(Color Plate I, fig. 17; Plate XIII, fig. 2)

1930. *N. fazi* Hungerford. Bull. Brook. Ento. Soc., xxv, pp. 141-142, fig. 1.

Referring to this species, also:

1897. *N. americana* Kirkaldy. Trans. Ento. Soc. London, p. 409, 1897. ("Chili, Valdivia Hamb. Mus.").

1899. *N. undulata* Kirkaldy. Above specimen redetermined by Kirkaldy (not published).

1901. *N. virescens* Reed. Revista Chilena de Historia Natural, v. Reprint "Sinopsis de los Hemipteros de Chile, p. 106.

Size. Length, 12 mm.; width of pronotum, 4 mm. Males a little smaller.

Color. General facies dark. Head, anterior part of pronotum

and legs pale yellow. Posterior half of pronotum darkened by the black mesothorax beneath, scutellum black. Hemelytra reddish brown to black marked with tan; the tan markings are variable, typically as follows: on base of clavus and extending as indefinite streak near the outer margin to near its tip; a small area near base of corium sometimes lacking, another of variable form in outer half of corium, sometimes, but not usually, reaching membrane; membrane dark, sometimes with a pale spot on distal half, sometimes with the tip pale instead. Venter dark, except connexivum, metaxyphus and parts of abdominal venter (especially fourth sternite) which are yellowish brown.

Structural Characteristics. Anterior outline of head, as viewed from above, truncate but slightly rounded; vertex slightly shorter than its anterior width in female but longer in the male; anterior margin of vertex less convex and shorter than the eye; anterior breadth of vertex : synthlipsis :: 3 + : 2; synthlipsis less than three-fifths as wide as an eye. Pronotum about twice as long as the head in the female, but sometimes less in the male, due to its relatively longer head; lateral margins not very divergent, straight; anterior angles embracing the eyes; lateral ledge somewhat oblique and shorter than the eye below it. Lobes of membrane about equal. Anterior trochanter of male with a hook. Mesotrochanters rounded. Last abdominal sternite of female notched at tip. Female gonapophyses (first pair) short. Male genital capsule as shown on Plate XIII.

Location of Type. Holotype, allotype and many paratypes in the Francis Huntington Snow Entomological Museum at the University of Kansas. Some paratypes in the U. S. N. M. and in the collection of J. R. de la Torre-Bueno. The types were collected for me by Doctor Alfredo Faz from Limache, Santiago and Termas Cauquenes, Chile.

Comparative Notes. This common Chilean species was known to Doctor Kirkaldy, who called it *N. americana* Fabr. in his 1897 paper and later labeled it *N. undulata* Say. Its short truncate head, general color pattern and male genitalia readily separate it from *N. undulata* Say. Its closest relative is *N. vereertbruggheni* Hungerford, from which it differs in its narrower vertex, less declivant head, more oblique lateral prothoracic ledge and shape of the male genital claspers.

Data on Distribution. Appears to be widespread in Chile, S. A., and extends north into Peru, S. A.

SOUTH AMERICA

CHILE: Besides those from type localities, I have seen: Valparaiso, R. Martin 1922 (Paris Museum); "Fundort?" (Berlin Museum); Valdivia, Chamelcha "Coll. Breddin" (Deutsches Entomologisches Museum, Berlin-Dahlem).
PERU: "Coll. Breddin" (Deutsches Entomologische Museum, Berlin-Dahlem).

Notonecta vereertbruggheni Hungerford, 1928

(Color Plate II, fig. 3; Plate XIII, fig. 4)

1928. *N. vereertbruggheni* Hungerford. Annals Ento. Soc. Amer., xxi, pp. 119, 120.
1930. *N. vereertbruggheni* Hungerford. Bull. Brooklyn Ento. Soc., xxv, p. 142, fig. 2 (Male genital capsule).

Size. Length, 11 mm. to 12 mm.; width of pronotum, 4.2 mm.

Shape. Normal as viewed from above. From the side the thorax appears more elevated than usual.

Color. General facies dark, typical coloring as follows: Head, anterior half of pronotum and limbs yellow, the last named often somewhat clouded. Posterior half of pronotum darkened by the black mesothorax beneath, scutellum black. Hemelytra black streaked with tan; clavus with longitudinal streak of tan; corium with a longitudinal pale stripe that is often obliterated in the middle, leaving tan spots on base and distal field; membrane black. Venter dark, except connexivum, metaxyphus and parts of abdominal venter (especially fourth sternite) which are yellowish brown.

Structural Characteristics. Head depressed; anterior outline, as viewed from above, rounded; vertex shorter than its anterior width; anterior margin of vertex nearly as convex as and longer than the eye; anterior breadth of vertex : synthlipsis :: 3:2; synthlipsis more than three-fifths as wide as an eye. Pronotum about twice as long as the head; lateral margins not very divergent, straight; anterior angles embracing the eyes; lateral ledge nearly horizontal in front two-thirds, somewhat deflected behind, shorter than rear margin of the eye below it. Lobes of membrane about equal. Anterior trochanter of male with a hook. Mesotrochanter rounded. Last abdominal sternite of female notched at tip. Female gonapophyses (first pair) short. Male genital capsule as shown on Plate XIII.

Location of Type. Francis Huntington Snow Entomological Museum at the University of Kansas. Some paratypes in the U. S. N. M. Described from 15 males and 11 females taken by Mr. Vereertbrugghen, in whose honor the species is named. This series includes the holotype, allotype and paratypes, which were captured in Rio Negro territory of Argentina, South America.

Comparative Notes. This species has the general facies of *N.*

fazi Hungerford from which it differs in the wider interocular space and in the shape of genital claspers of the males.

Data on Distribution. Known only from the type locality.

CHECK LIST OF *NOTONECTA*—LINNÆUS

Subgenus PARANECTA Hutchinson

1. *N. lactitans* Kirkaldy. (Africa.)
2. *N. minuta* Hungerford. (Bolivia, S. A.)
3. *N. peruviana* Hungerford. (Peru, S. A.)
4. *N. disturbata* Hungerford. (Brazil and Paraguay, S. A.)
5. *N. pulchra* Hungerford. (Paraguay, S. A.)
6. *N. bifasciata* Guérin. (Uruguay, S. A.)
7. *N. virescens* Blanchard. (Chile, S. A.)
8. *N. bicirca* Hungerford. (Chile, S. A.)
9. *N. bicircoidea* Hungerford. (Southern Argentina, S. A.)
10. *N. sellata* Fieber. (Argentina, Brazil, Paraguay and Bolivia, S. A.)
11. *N. polystolisma* Fieber. (Brazil, S. A.)
12. *N. vereertbruggheni* Hungerford. (Southern Argentina, S. A.)
13. *N. fazi* Hungerford. (Chile and Peru, S. A.)
14. *N. variabilis* Fieber. (Brazil, S. A.)
15. *N. indica* Linnæus. (South, Central and North America.)
16. *N. confusa* Hungerford. (South America.)
17. *N. undulata* Say. (North America.)
18. *N. distinctoidea* Hungerford. (Mexico.)
19. *N. indicoidea* Hungerford. (Mexico.)
20. *N. raleighi* Bueno. (Southern U. S., America.)
21. *N. lunata* Hungerford. (Northern U. S., America, and Canada.)
22. *N. unifasciata unifasciata* Guérin. (Mexico.)
23. *N. u. cochisiana* Hungerford. (Arizona, U. S. A.)
24. *N. u. angulata* Hungerford. (South America.)
25. *N. u. andersoni* Hungerford. (Western U. S. A. and B. C. Canada.)
26. *N. spinosa* Hungerford. (Northwestern U. S. A. and B. C. Canada.)
27. *N. kiangsis* Kirkaldy. (China and Eastern Siberia.)
28. *N. uhleri* Kirkaldy. (Southeastern U. S. A.)
29. *N. kirkaldyi* Martin. (China.)
30. *N. saramoa* Esaki. (Formosa.)
31. *N. chinensis* Fallou. (China.)
32. *N. immediata* Kiritshenko. (Eastern Siberia.)
33. *N. triguttata* Motschulsky. (Japan.)
34. *N. insulata* Kirby. (Eastern U. S. A. and Canada.)
35. *N. kirbyi* Hungerford. (Western U. S. A. and Canada.)
36. *N. impressa* Fieber. (Mexico.)
37. *N. montezuma* Kirkaldy. (Mexico and Texas, U. S. A.)

Subgenus BICHROMONECTA Hungerford

38. *N. melaena* Kirkaldy. (Mexico.)
39. *N. ochrothoe* Kirkaldy. (Southern California to Colombia, S. A.)

40. *N. colombiana* Hungerford. (Colombia, S. A.)
41. *N. repanda* Hungerford. (Arizona to Mexico.)
42. *N. shooteri* Uhler. (California.)

Subgenus ERYTHRONECTA Hungerford

43. *N. hoffmanni* Hungerford. (California, Arizona and Lower California.)
44. *N. ceres ceres* Kirkaldy. (Costa Rica.)
45. *N. c. stirtoni* Hungerford. (Mexico.)
46. *N. c. rogersi* Hungerford. (Costa Rica.)
47. *N. compacta* Hungerford. (Mexico.)
48. *N. robusta* Hungerford. (Mexico.)
49. *N. mexicana* Amyot and Serville. (Mexico.)
50. *N. m. creaseri* Hungerford. (Mexico.)
51. *N. hintoni* Hungerford. (Mexico.)
52. *N. lobata* Hungerford. (New Mexico, Texas, Mexico.)

Subgenus NOTONECTA Linnæus

53. *N. maculata* Fabricius. (Europe, North Africa east to India.)
54. *N. canariensis* Kirkaldy. (Canary Islands.)
55. *N. pallidula* Poisson. (Algeria and Morocco.)
56. *N. meinertzhageni* Poisson. (Hoggar Mts., Sahara, Africa.)
57. *N. arabiensis* Hungerford. (Arabia.)
58. *N. lutea* Müller. (Northern Europe, Siberia.)
59. *N. borealis* Bueno and Hussey. (Northern North America.)
60. *N. reuteri* Hungerford. (Northern Europe.)
61. *N. viridis viridis* Delcourt. (France and England.)
62. *N. v. mediterranea* Hutchinson. (About Mediterranian and eastward to India.)
63. *N. v. kashmiriana* Hungerford. (Kashmir.)
64. *N. glauca glauca* Linnæus. (Europe.)
65. *N. g. poissoni* Hungerford. (Asia Minor.)
66. *N. g. hybrida* Poisson. (Southern France to North Africa.)
67. *N. g. rufescens* Poisson. (Guernsey Islands.)
68. *N. g. fulva* Fuente. (Iberian Peninsula.)
69. *N. g. kirvillei* Poisson. (Asia Minor.)
70. *N. nigra* Fieber. (Brazil.)
71. *N. obliqua obliqua* Gallen. (Northern and Middle Palearctic.)
72. *N. o. meridionalis* Poisson. (About the Mediterranian.)
73. *N. o. delcourti* Poisson. (Belgium and Northwest France.)
74. *N. amplifica* Kiritshenko. (Southeastern Siberia.)
75. *N. violacea* Kirkaldy. (Burma.)
76. *N. montandoni* Kirkaldy. (China.)
77. *N. irrorata* Uhler. (Eastern North America.)

Subgenus ENITHARONECTA Hungerford

78. *N. handlirschi* Kirkaldy. (Australia.)

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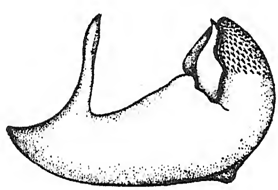
ADDENDA

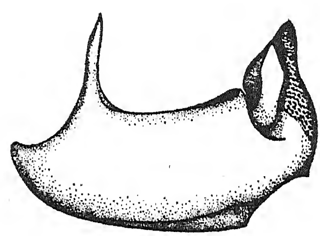
(Incomplete references not seen by me)

MALEK. Biol. Zbl. L., p. 182. (A study of the orientation of *N. glauca* L.) 1930?

KERTESZ ROVART. Lap. XXIV, p. 163. (Experiments on feeding habits of *N. glauca* L.) 1930?



N. virescens.



N. peruviana.

TEXT FIGURE 8. Male genital capsules of *N. virescens* Blanchard and *N. peruviana*, new species. Drawn by Philip Levercault.

INDEX

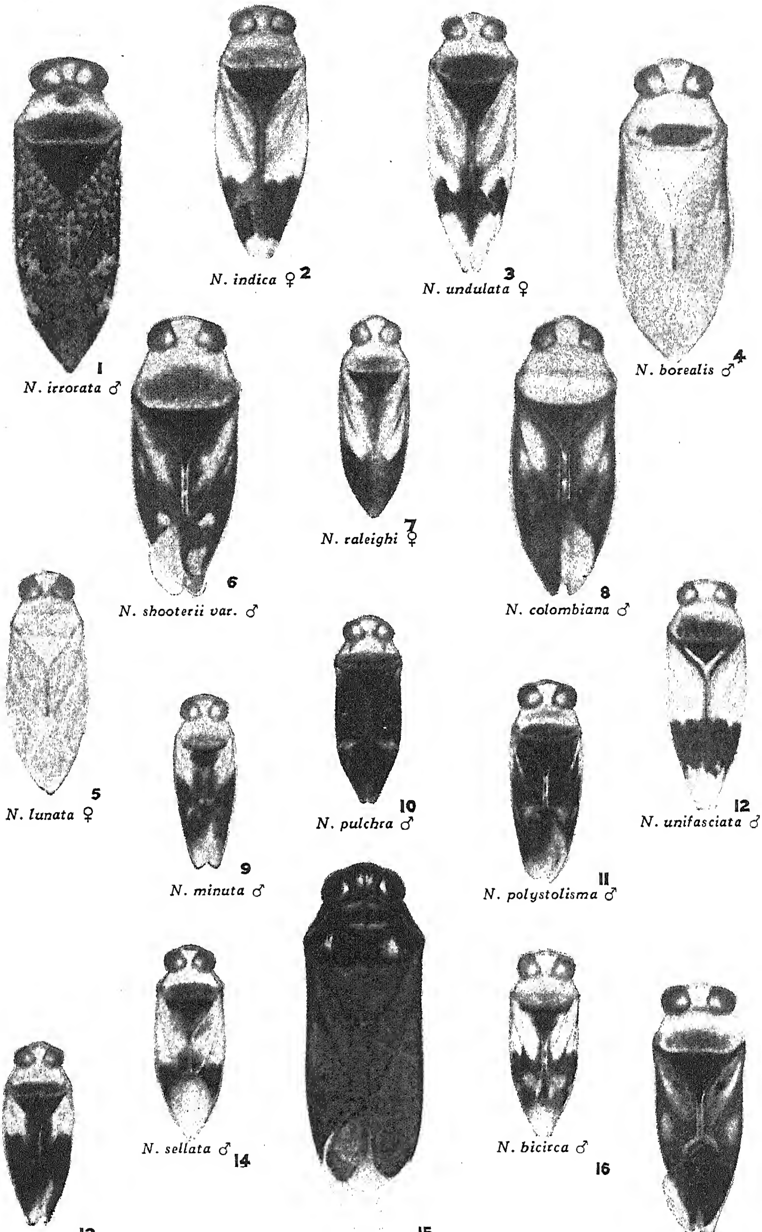
COLOR PLATE I

(Magnification approximately × 3)

WESTERN HEMISPHERE NOTONECTA

FIGURE

1. *Notonecta irrorata* Uhler. Range: Eastern Canada and eastern half of United States, from Canada to the Gulf and westward to eastern Kansas. (See page 92.)
2. *Notonecta indica* Linn. Range: Across southern United States south of 37° latitude and southward through insular America (Greater Antilles) and through Mexico to Colombia, S. A. (See page 113.)
3. *Notonecta undulata* Say. Range: Across southern Canada and throughout United States from coast to coast and south to northern Mexico. The most common species in the United States. (See page 117.)
4. *Notonecta borealis* Bueno and Hussey. Range: Canada and northernmost states of the United States. Distribution inadequately known, but a Boreal species. (See page 95.)
5. *Notonecta lunata* Hungerford. Range: Eastern Canada and eastern United States. (See page 107.)
6. *Notonecta shooteri* Uhler. Range: The species (lat. sens.) ranges from California through Arizona to Mexico. The specimen drawn is from Mexico, D. F. (See page 101.)
7. *Notonecta raleighi* Bueno. Range: Southeastern states of United States. (See page 105.)
8. *Notonecta colombiana* Hungerford. Range: Described from Colombia, S. A., previously confused with *N. shooteri* Uhler. (See page 128.)
9. *Notonecta minuta* Hungerford. Range: Described from Prov. del Sara, Bolivia, S. A. (See page 138.)
10. *Notonecta pulchra* Hungerford. Range: This is a very common species in Paraguay, S. A. (See page 131.)
11. *Notonecta polystolisma* Fieber. Range: Common in the region of Sao Paulo, Brazil. (See page 132.)
12. *Notonecta unifasciata* Guérin. Range: (Lat. sens.) From Mexico across western United States to western Canada. (See page 109.)
13. *Notonecta disturbata* Hungerford. Range: Known only from "Brazil," but doubtless region around Sao Paulo. (See page 140.)
14. *Notonecta sellata* Fieber. Range: Argentina, Paraguay and southern Brazil. (See page 139.)
15. *Notonecta nigra* Fieber. Range: Described from Brazil, but doubtful. See discussion under name. (See page 126.)
16. *Notonecta bicirca* Hungerford. Range: Chile, S. A. A common species easily confused with *N. bicircoidea* Hungerford and with *N. virescens* Blanchard. (See page 137.)
17. *Notonecta fazi* Hungerford. Range: Very common in Chile, ranging northward into Peru. (See page 142.)



1 *N. irrorata* ♂

2 *N. indica* ♀

3 *N. undulata* ♀

4 *N. borealis* ♂

5 *N. lunata* ♀

6 *N. shooterii var.* ♂

7 *N. raleighi* ♀

8 *N. colombiana* ♂

9 *N. minuta* ♂

10 *N. pulchra* ♂

11 *N. polystolisma* ♂

12 *N. unifasciata* ♂

13 *N. disturbata* ♂

14 *N. sellata* ♂

15 *N. nigra* ♀

16 *N. bicirca* ♂

17 *N. fazi* ♂

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COLOR PLATE II

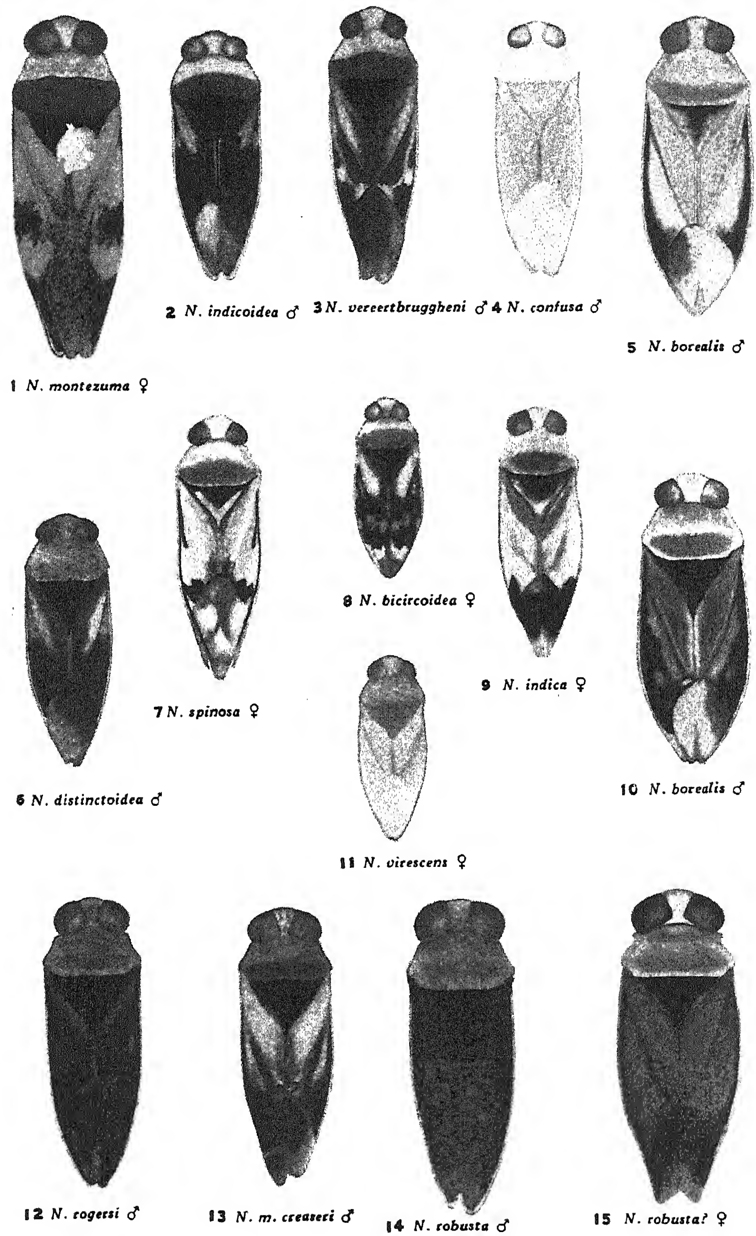
(Magnification approximately × 3)

WESTERN HEMISPHERE NOTONECTA

FIGURE

1. *Notonecta montezuma* Kirkaldy. Range: Mexico into Tex U. S. A. (See page 82.)
2. *Notonecta indicoidea* Hungerford. Range: Described from Mexco, D. F. (See page 123.)
3. *Notonecta vereertbruggheni* Hungerford. Range: Described from Rio Negro, territory of Argentina. Compare with *N. fazi* Hungerford on Plate I. (See page 144.)
4. *Notonecta confusa* Hungerford. Range: Known only by the type which was labeled "S. Amer." (See page 130.)
5. *Notonecta borealis* Bueno and Hussey. Range: See Plate I, figure 4, and this plate, figure 10. A study in melanchroism. (See discussion under this species, page 95.)
6. *Notonecta distinctoidea* Hungerford. Range: Known only from Mexico. (See page 124.)
7. *Notonecta spinosa* Hungerford. Range: Described from Utah and now known from Nevada, Montana, Oregon, and British Columbia, Canada. (See page 112.)
8. *Notonecta bicircoidea* Hungerford. Range: Described from Rio Negro, territory of Argentina. Compare with *N. bicirca* Hungerford on Plate I. (See page 136.)
9. *Notonecta indica* Linn. Range: (See Plate I.) This specimen has color of the type specimen, and until carefully studied led to confusion with *Notonecta unifasciata* Guérin. (See Plate I, figure 12, and page 113.)
10. *Notonecta Borealis* Bueno and Hussey. (See figure 5 and page 95.)
11. *Notonecta virescens* Blanchard. Specimen from Paris Museum.
12. *Notonecta rogersi* Hungerford. Now considered by me to be a subspecies of *Notonecta ceres* Kirkaldy. (See page 81.)
13. *Notonecta mexicana creaseri* Hungerford. Range: Known only from type locality in Mexico. (See page 77.)
14. *Notonecta robusta* Hungerford. Range: Type bears no label, but I believe it comes from Chiapas, Mexico. (See page 78.)
15. *Notonecta robusta?* Hungerford. Range: Female specimen from San Cristobal, Chiapas, Mexico, taken by A Dampf, and I believe it to be female of *N. robusta*. (See page 78.)

HUNGERFORD—*Notonecta*—PLATE II.



1 *N. montezuma* ♀
2 *N. indicoidea* ♂
3 *N. vereertbruggheni* ♂
4 *N. confusa* ♂
5 *N. borealis* ♂
6 *N. distinctoidea* ♂
7 *N. spinosa* ♀
8 *N. bicircoidea* ♀
9 *N. indica* ♀
10 *N. borealis* ♂
11 *N. virescens* ♀
12 *N. rogersi* ♂
13 *N. m. creaseri* ♂
14 *N. robusta* ♂
15 *N. robusta?* ♀

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Kathleen Doering
Delineator

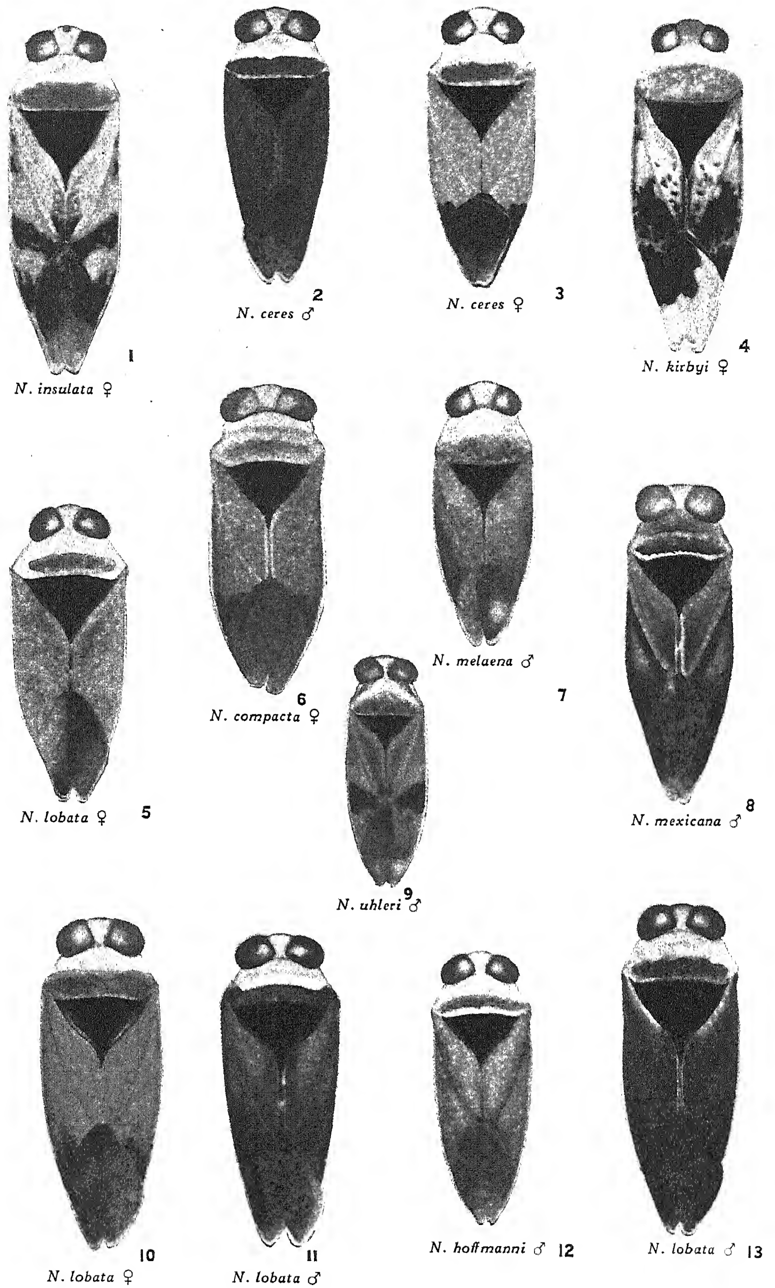
COLOR PLATE III

(Magnification approximately × 3)

WESTERN HEMISPHERE NOTONECTA

FIGURE

1. *Notonecta insulata* Kirby. Range: Eastern Canada and United States north of fortieth degree of latitude and east of one hundredth meridian. (See page 84.)
2. *Notonecta ceres* Kirkaldy. Range: A common species in Costa Rica. The female shown in figure 3 was named as *N. mexicana* var. *ceres* and the male as *N. mexicana* var. *hades* by Kirkaldy. (See page 79.)
3. *Notonecta ceres* Kirkaldy. (See note above.)
4. *Notonecta kirbyi* Hungerford. Range: Western Canada and Western United States. Hemelytra more often red and black than like the illustration. (See page 88.)
5. *Notonecta lobata* Hungerford. Range: Found in Texas, New Mexico and Arizona. An abundant species in Arizona. Have seen specimens labeled "Mexico." In this species the females are colored as in figures 5 and 10. The males are nearly always darker (see figures 11 and 13.) (See page 70.)
6. *Notonecta compacta* Hungerford. Range: Known from the states of Guerrero and Colima, Mexico. The males are nearly black as in *N. ceres* Kirkaldy and *N. lobata* Hungerford. (See page 73.)
7. *Notonecta melaena* Kirkaldy. Range: States of Jalisco, Guanajuato and Lower California, Mexico. The typical color is darker than the specimen shown. (See page 97.)
8. *Notonecta mexicana* Amyot and Serville. Range: Mexico, but appears to be by no means as common as other species that have been mistaken for it, *N. lobata* Hungerford, for example. (See page 75.)
9. *Notonecta uhleri* Kirkaldy. Range: In United States from Massachusetts south to Mississippi. Its western limit appears to be Illinois and southward, east of Mississippi River. (See page 103.)
10. *Notonecta lobata* Hungerford. (See figure 5.) A typical female. (See page 70.)
11. *Notonecta lobata* Hungerford. A male, showing that the red males are darker than the females. (See page 70.)
12. *Notonecta hoffmanni* Hungerford. Range: California and Arizona in the United States and Lower California in Mexico. (See page 68.)
13. *Notonecta lobata* Hungerford. Range: (See figure 5.) The usual color of the male, and showing its size to be a little larger than the female (see figure 10). (See page 70.)



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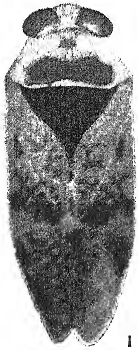
COLOR PLATE IV

(Magnification approximately × 3)

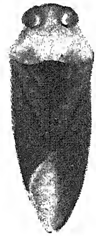
EASTERN HEMISPHERE NOTONECTA

FIGURE

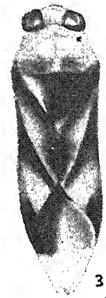
1. *Notonecta montandoni* Kirkaldy. Range: Tibet, south and eastward in China. (See page 37.)
2. *Notonecta handlirschi* Kirkaldy. Range: Known only from West Australia. Only member of the genus known from Australia. (See page 27.)
3. *Notonecta lactitans* Kirkaldy. Range: South Africa, and to date the only member of the genus known south of the Sahara. (See Plate V, figure 12, for the male.) (See page 28.)
4. *Notonecta triguttata* Motschulsky. Range: Japan; may occur in eastern China, but not confirmed by me. (See page 36.)
5. *Notonecta marmorea marmorea.* This is not *N. m. marmorea* Fabr. It comes from Morocco and may be a very pale specimen of *N. viridis mediterranea* Hutchinson, but I really believe that it is *N. viridis viridis* Delcourt. *N. viridis mediterranea* Hutchinson typically has more nearly the color pattern of my *N. viridis kashmiriana.* (Plate V.)
6. *Notonecta obliqua obliqua* Gallén. Range: Northern and middle palæarctic. A well-known European species. (See page 51.)
7. *Notonecta lutea* Müller. Range: Northern Europe. (See page 56.)
8. *Notonecta canariensis* Kirkaldy. Range: Canary Islands. (See page 40.)
9. *Notonecta reuteri* Hungerford. Range: Northern Europe. (See page 59.)
10. *Notonecta glauca* Linnæus. Range: Widely distributed over Europe. (See page 46.)
11. *Notonecta violacea* Kirkaldy. Range: Burma. (See page 45.)



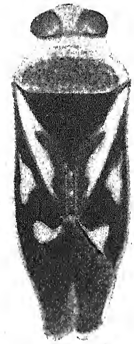
1
N. montandoni ♂



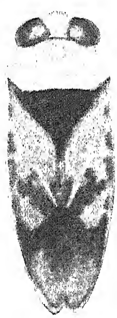
2
N. handlirschi ♂



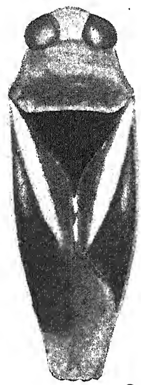
3
N. lactitans ♀



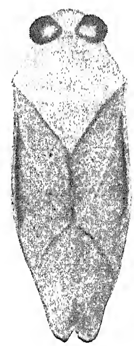
4
N. triguttata ♀



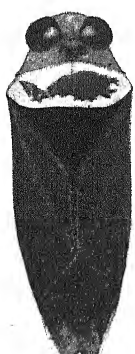
5
N. m. marmorea ♂



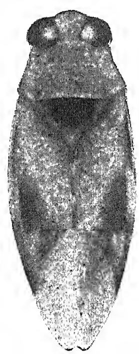
6
N. o. obliqua ♂



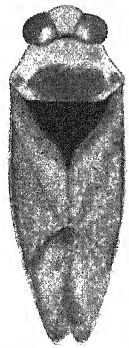
N. lutea ♂ 7



N. canariensis ♀ 8



N. reuteri ♂ 9



N. glauca ♂ 10

11
N. violacea ♂

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COLOR PLATE V

(Magnification approximately × 3)

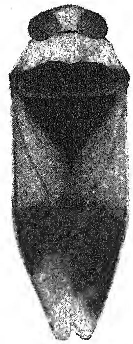
EASTERN HEMISPHERE NOTONECTA

FIGURE

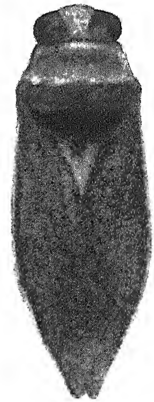
1. *Notonecta arabiensis* Hungerford. Range: Known only from type specimens from Arabia. (See page 44.)
2. *Notonecta pallidula* Poisson. Range: Algeria and Morocco of North Africa. (See page 38.)
3. *Notonecta glauca poissoni* Hungerford. This is one of the specimens mentioned by Kirkaldy on page 421 of his revision. It comes from Máli—Nousky, Erzerum. There are eight specimens of this in Vienna. (See page 49.)
4. *Notonecta amplifica* Kiritshenko. Range: Southeastern Siberia. (See page 55.)
5. *Notonecta obliqua meridionalis* Poisson. Range: Around the Mediterranean. (See page 54.)
6. *Notonecta immediata* Kiritshenko. Range: Eastern Siberia. I cannot distinguish this structurally from *N. triguttata* Motsch. (See page 35.)
7. *Notonecta kiangsis* Kirkaldy. Range: Central and Northern China and Eastern Siberia. (See page 33.)
8. *Notonecta chinensis* Fallou. Range: A common species in China. (See page 31.)
9. *Notonecta kirkaldyi* Martin. Range: Described from Yun-Nan-Nansen. China. (See page 30.)
10. *Notonecta maculata maculata* Fabricius. Range: Western Europe, south from Denmark to North Africa and eastward to Baluchistan.
11. *Notonecta glauca fulva* Fuente. Range: Not well established, but described from Iberian Peninsula. The specimen shown is from Guernsey Island. This form needs further study as to identity and relationships. (See page 50.)
12. *Notonecta lactitans* Kirkaldy. Range: (See Plate IV, figure 3.) This male was called variety *stygica* by Kirkaldy, but is only the male of the above species. (See page 28.)
13. *Notonecta viridis kashmiriana* Hungerford. Range: Kashmir. (See page 65.)
14. *Notonecta m. viridis* Delcourt according to Esaki. I believe should be *N. viridis viridis* Delcourt. Range: England and France. (See page 60.) The specimen here shown is an unusually highly colored specimen from Gravesend, England.

1 *N. arabiensis* ♀

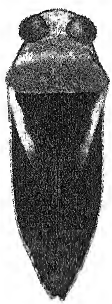
2 *N. pallidula* ♂



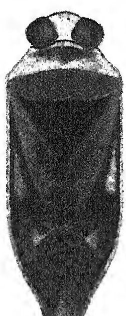
3 *N. glauca var.* ♀



4 *N. amplifica* ♂

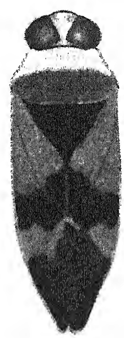


5 *N. o. meridionalis* ♂

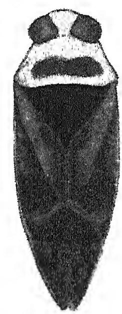


6 *N. immediata* ♀

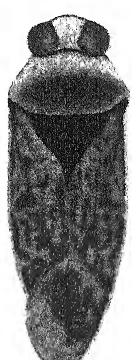
7 *N. kiangsis* ♀



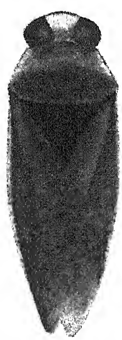
8 *N. chinensis* ♂



9 *N. kirkaldyi* ♂

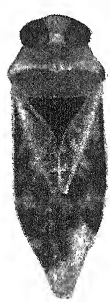


10 *N. m. maculata* ♀



11 *N. m. fulva* ♂

12 *N. lactitans* ♂



13 *N. kashmiriana* ♂

14 *N. m. viridis* ♂

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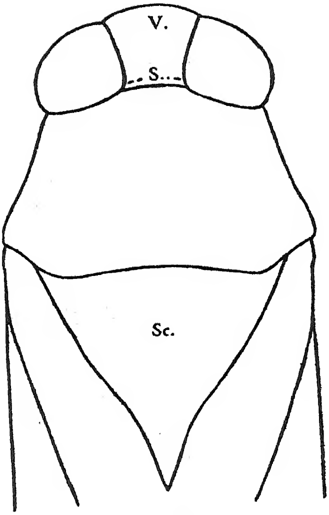
PLATE VI

This plate illustrates the genera of the family Notonectidæ.

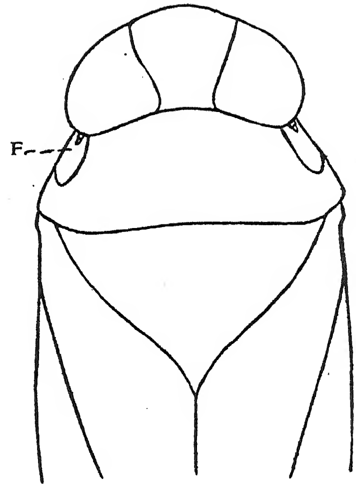
FIGURE

1. Notonecta. Anterior half of dorsum. V = vertex; S = synthlipsis; Sc. = scutellum.
2. Enithares. Anterior half of dorsum. Note that the anterolateral margins of prothorax are foveate, indicated in drawing by F.
3. Nychia. Shows the foveate prothorax.
4. Martarega. Compare with figure 3. The genus Martarega is from Western Hemisphere, while Nychia is found in Africa.
5. Notonecta. Middle femur, showing the anteapical tooth or pointed protuberance, characteristic of the tribe Notonectini.
6. Paranisops. On the left is the form with large scutellum and developed wings; on the right is the form with small scutellum and reduced metathoracic wings. Note the claval orifice just behind the scutellum.
7. Buenoa. Anterior half of dorsum to show the claval orifice (0) just behind the scutellum. In the key this is called the hemelytral commissure pit.

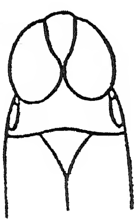
PLATE VI

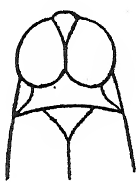


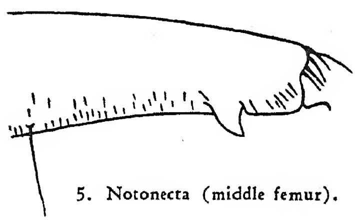
1. Notonecta.

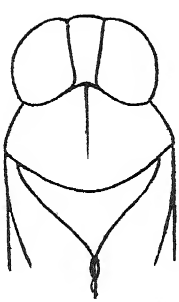


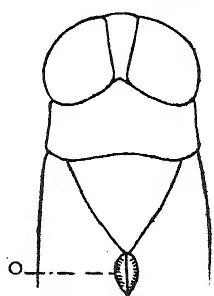
2. Enithares.


3. Nychia.


4. Martarega.


5. Notonecta (middle femur).


6. Paranisops.



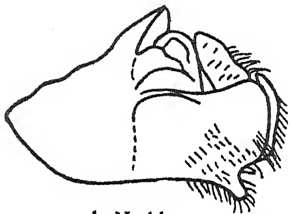
7. Buenoa.

PLATE VII

FIGURE

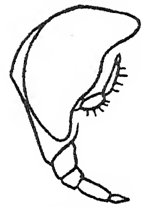
1. Nychia. Genital capsule of male viewed from the left side. Note that the capsule is cleft behind and that the claspers or parameres are unlike on the two sides. (After Hutchinson.)
2. Martarega. Side view of the head, showing the four-segmented antenna; the terminal segment is small. Nychia has lost the terminal segment.
3. Martarega. Genital capsule of the male viewed from the left side. Note that the capsule is cleft behind and that the claspers are unlike. (After Jaczewski.)
4. Buenoa. Genital capsule of the male viewed from left side. The capsule is not cleft behind; the claspers are unlike.
5. Anisops. Left anterior leg of male (inside or anterior view) shows the one-segmented tarsus and stridular area (Str.) on tibia.
6. Buenoa. Right anterior leg of male. Shows the two-segmented tarsus and stridular areas (Str.) on femur and tibia.

PLATE VII

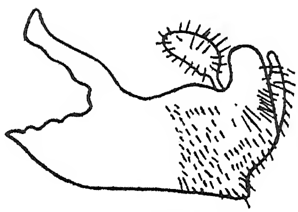


right clasper

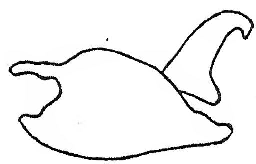
1. Nychia.



2. Martarega.



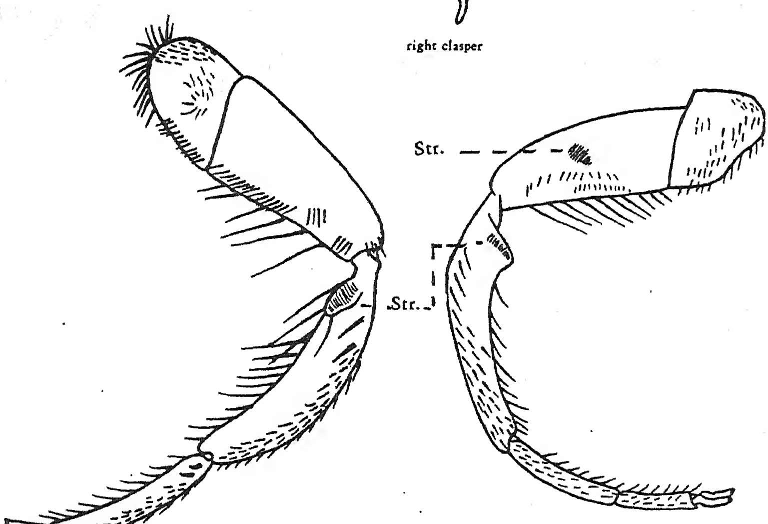
right clasper



3. Martarega.

right clasper

4. Buenoa.



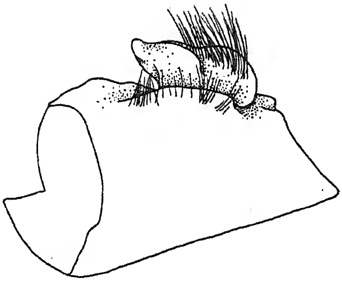
5. Anisops (anterior leg ♂). 6. Buenoa (anterior leg ♂).

PLATE VIII

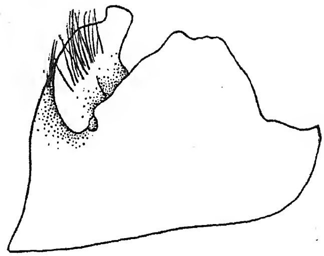
FIGURE

1. *Enithares brasiliensis* Spinola. Genital capsule of male viewed from left side.
2. *Enithares brasiliensis* Spinola. Genital capsule of male viewed from right side. Note the differences in claspers or parameres.
3. *Paranisops inconstans* var. *lutea* Hale. Male genital capsule viewed from left side. The parameres (P) are alike.
4. *Notonecta handlirschi* Kirkaldy (subg. Enitharonecta.) Male genital capsule viewed from the left side. The parameres are alike.
5. Notonecta. Head and pronotum to show the anterior margin of vertex for comparison with figure 8.
6. Buenoa. Genital capsule viewed from right side. R. C. = right clasper L. C. = left clasper.
7. Buenoa. Genital capsule viewed from the left side. Note the differences in the parameres or claspers. L. C. = left clasper. R. C. = right clasper.
8. Notonecta. Head and pronotum—to compare shape with figure 5. (See, also, Plate XVII, figure 4.)
9. *Notonecta lactitans* Kirkaldy (subg. Paranecta.) Genital capsule viewed from the left side.

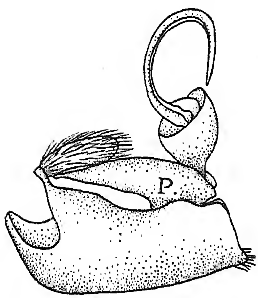
PLATE VIII



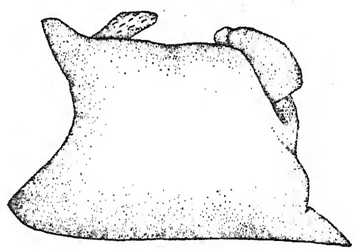
1. Enithares brasiliensis (left side).



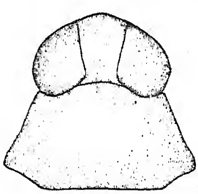
2. Enithares brasiliensis (right side).



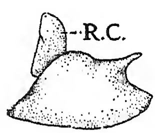
3. Paranisops inconstans var. lutea



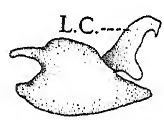
4. N. handlirschi (subg. Enitharonecta).



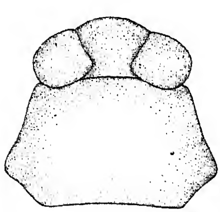
5. Notonecta---head and pronotum.



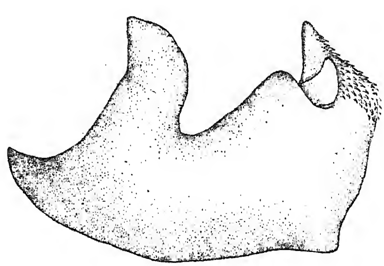
6. Buenoa---(right side).



7. Buenoa---(left side).



8. Notonecta---head and pronotum.



9. N. lactitans (subg. Paranecta).

PLATE IX

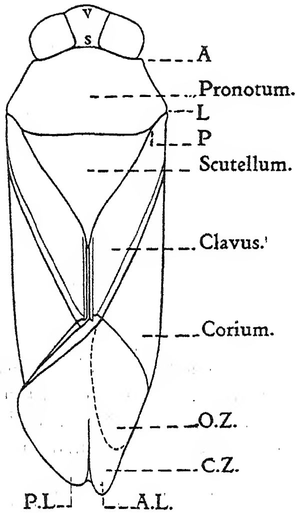
FIGURE

1. Notonecta Dorsal view:

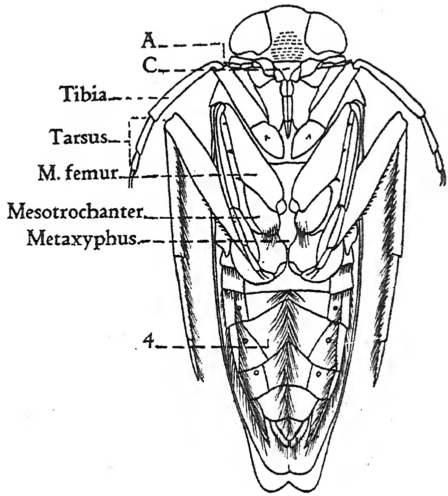
   V = vertex.
   S = synthlipsis.
   A. angle = anterior lateral angle of the pronotum.
   L. angle = lateral angle of pronotum.
   P. angle = posterior angle of pronotum.
   O. Z. = opaque zone of membrane.
   C. Z. = clear zone of membrane.
   A. L. = anterior lobe of membrane.
   P. L. = posterior lobe of membrane.

2. Notonecta. Male, ventral view, showing antenna (A); beak, showing clypeus (C); the three pairs of legs, showing the hook on the anterior trochanters; metaxyphus and fourth abdominal sternite (4.)
3. *N. undulata* Say. Trochanter of male, to show the hook. This hook may be lacking in some species, represented by small proturbance or greatly enlarged as shown in figure 4.
4. *Notonecta shooteri* Uhler. Anterior trochanter of male, to show greatly enlarged hook and basal proturbance.
5. Middle leg of a Notonecta, with rounded trochanter.
6. Trochanter and basal part of femur of a Notonecta, to show spinose mesotrochanter.
7. *Notonecta handlirschi* Kirkaldy. Middle leg, without coxa.
8. *Notonecta lactitans* Kirkaldy. Middle leg.
9. Middle leg of a Notonecta to show the mesotrochanter with angle produced.

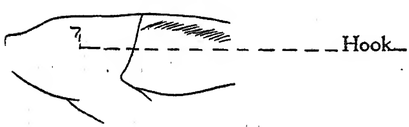
PLATE IX



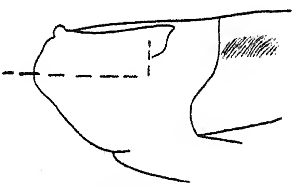
1. Notonecta (dorsum).



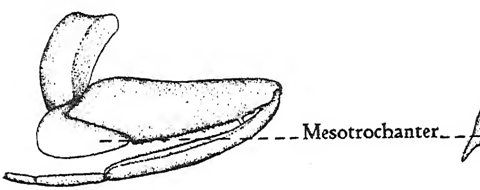
2. Notonecta (venter).



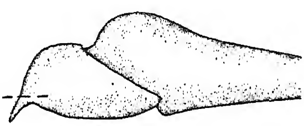
3. N. undulata (male).



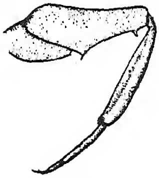
4. N. shooterii (male).



5. Mesotrochanter rounded.

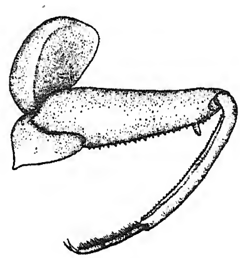


6. Mesotrochanter spinose.



7. N. handlirschi.

8. N. lactitans.



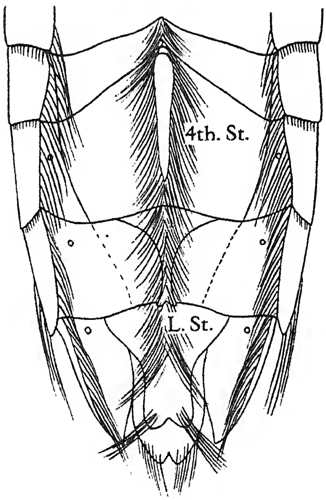
9. Mesotrochanter angle produced.

PLATE X

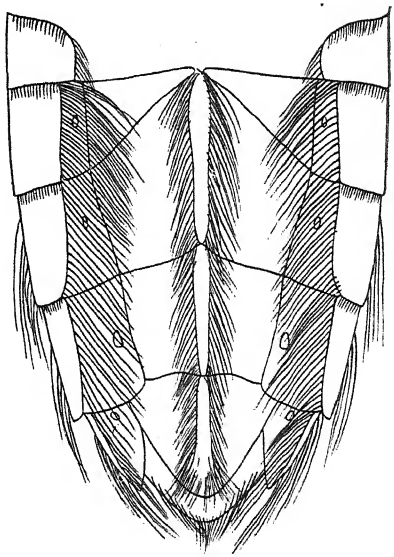
FIGURE

1. *Notonecta lobata* Hungerford. Ventral view of abdomen of female. Note that the carina of the fourth abdominal sternite (4th St.) is bare, that the fifth sternite is narrow and notched at tip and that the last abdominal sternite (L. St.)—typical for *N. mexicana* group—is characteristically different from the others.
2. *Notonecta montezuma* Kirkaldy. Ventral view of abdomen of female. Note that the carina is bare on fourth, fifth and most of sixth sternites. The last sternite is intermediate between the *Notonecta undulata* Say group and the *Notonecta irrorata* Uhler group.
3. *Notonecta undulata* Say. Ventral view of abdomen of female. Note the notch in the distal end of the fifth sternite and the notch in the tip of the last abdominal sternite.
4. *Notonecta irrorata* Uhler. Ventral view of abdomen of female. Note that the last abdominal sternite is large and constricted before the tip, which is not notched.

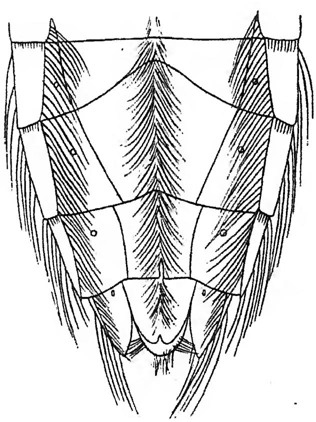
PLATE X



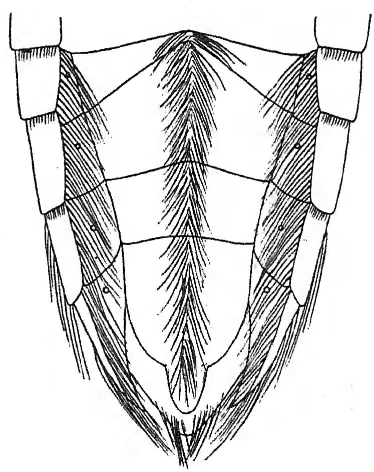
1. N. lobata (abdominal venter, female).



2. N. montezuma (abdominal venter, female)



3. N. undulata (abdominal venter, female).



4. N. irrorata (abdominal venter, female)

PLATE XI

The *Notonecta mexicana* group. Male genital capsules viewed from the left side. Figures 4, 5, 8, and 9 are sketches of the tip of the "internal stay," which in this group is large and strongly sclerotized.

PLATE XI

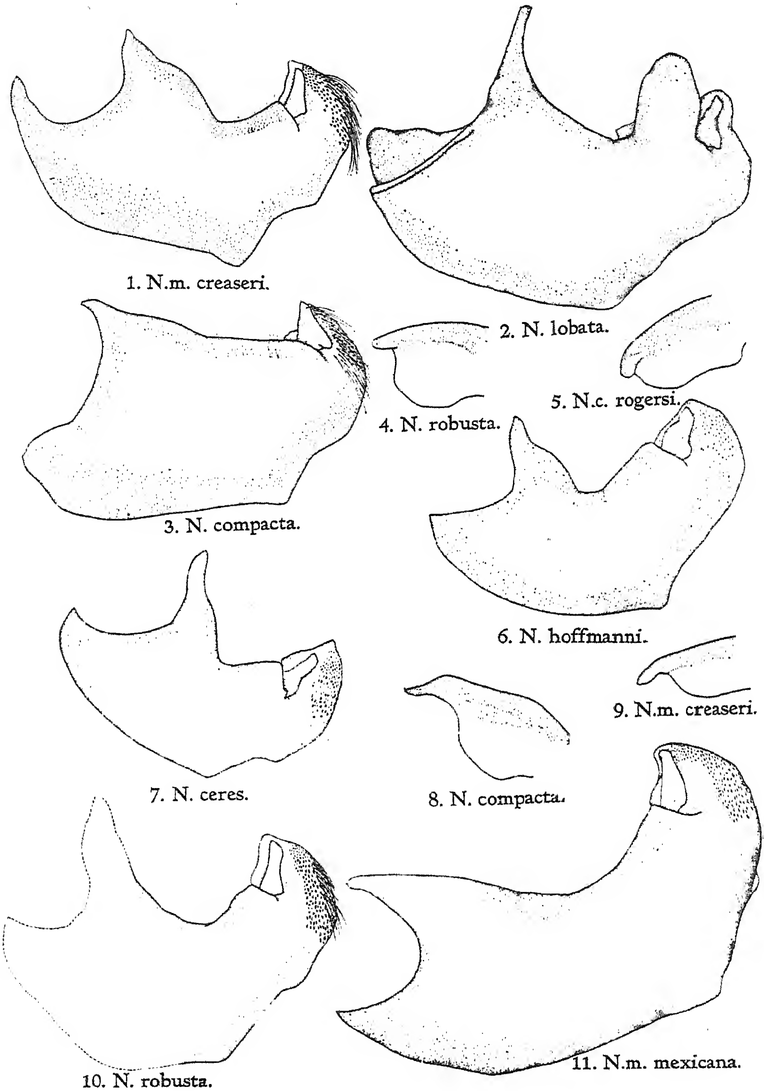
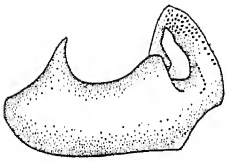

1. N.m. creaseri.
2. N. lobata.
3. N. compacta.
4. N. robusta.
5. N.c. rogersi.
6. N. hoffmanni.
7. N. ceres.
8. N. compacta.
9. N.m. creaseri.
10. N. robusta.
11. N.m. mexicana.

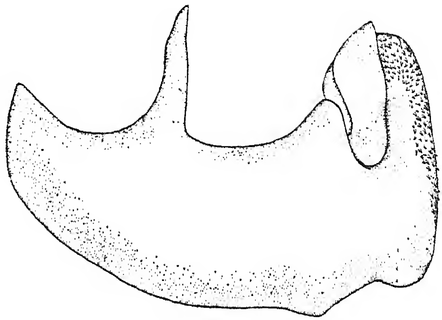
PLATE XII

The male genital capsules of some South American Notonecta. Views from the left side.

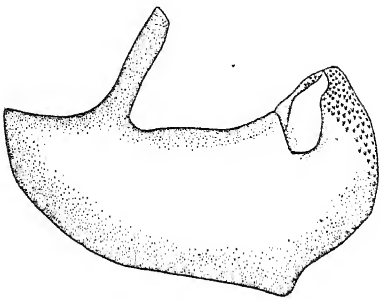
PLATE XII



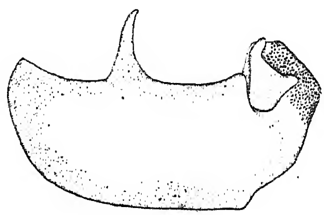
1. N. bifasciata (type).



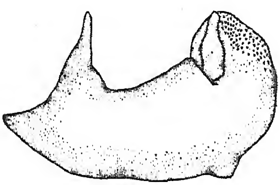
2. N. polystolisma.



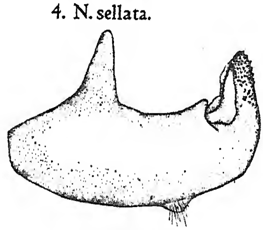
3. N. bicircoidea.



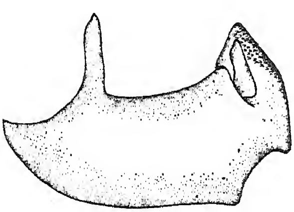
4. N. sellata.



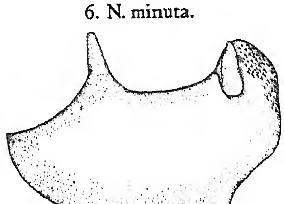
5. N. bicirca.



6. N. minuta.



7. N. disturbata.

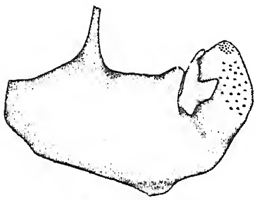


8. N. pulchra.

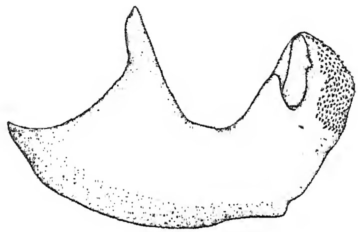
PLATE XIII

The male genital capsules of some American Notonecta belonging to the subgenus Paranecta.

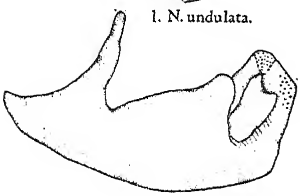
PLATE XIII



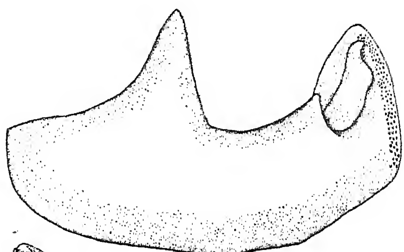
1. N. undulata.



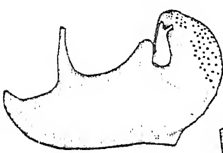
2. N. fazi.



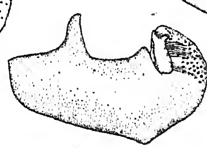
3. N. indica.



4. N. vereertbruggheni.

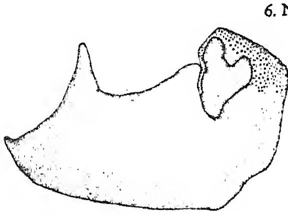


5. N. lunata.

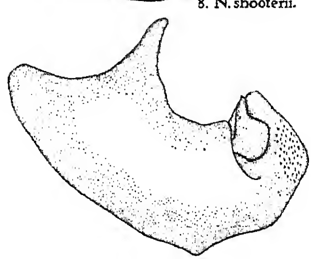


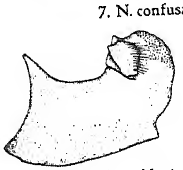
6. N. raleighi.

8. N. shooterii.

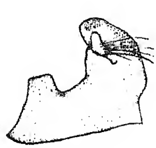


7. N. confusa.





9. N. distinctoidea.



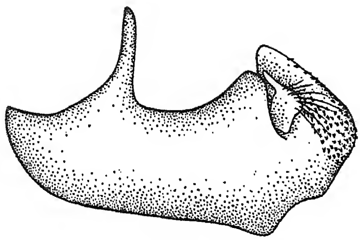
10. N. uhleri.

11. N. melaena.

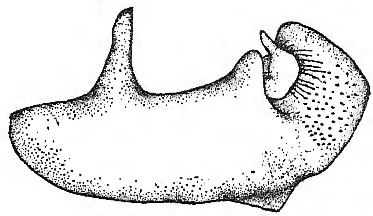
PLATE XIV

The male genital capsules of *Notonecta unifasciata* Guérin, its subspecies and close relatives.

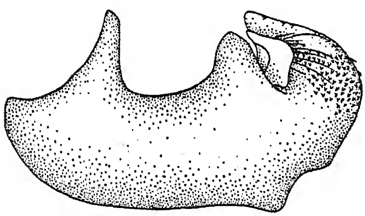
PLATE XIV



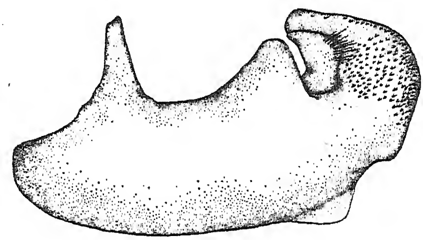
1. N. unifasciata (paratype).



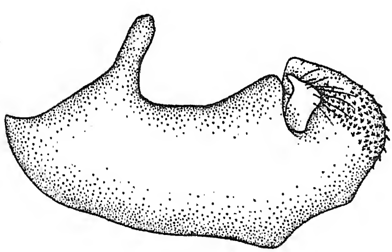
2. N. unifasciata.



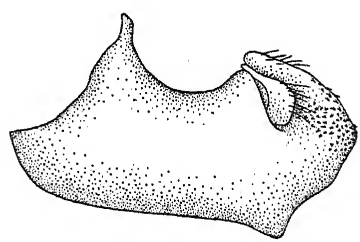
3. N. unifasciata.



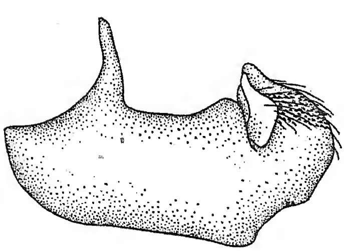
4. N. u. angulata.



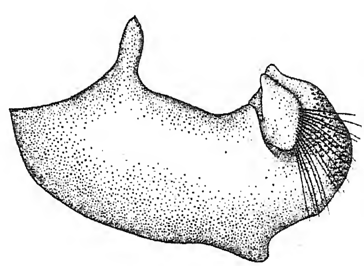
5. N. u. cochisiana.



6. N. u. andersoni.



7. N. spinosa.



8. N. indicoidea.

PLATE XV

The male genital capsules of some Notonecta.

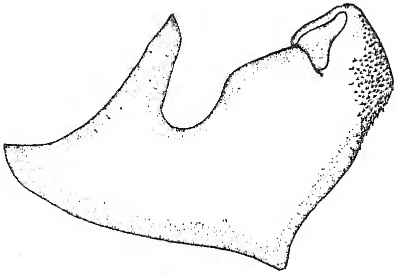
Figures 1, 2 and 4 are North American species and the others are oriental.

Figures 3, 5 and 8 are from China.

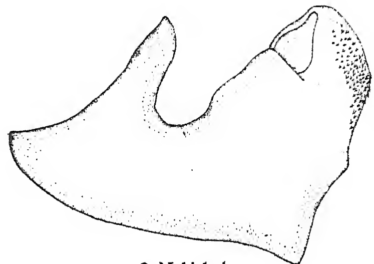
Figure 6 is from Japan.

Figure 7 is from Formosa.

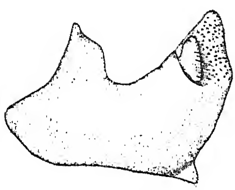
PLATE XV



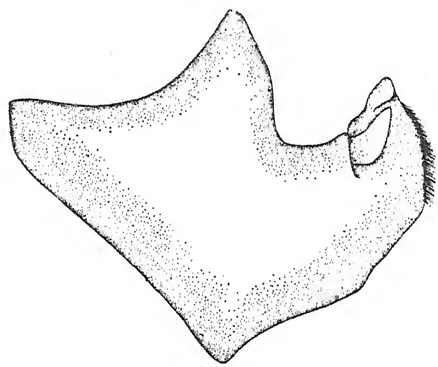
1. N. insulata.



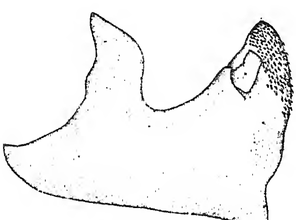
2. N. kirbyi.



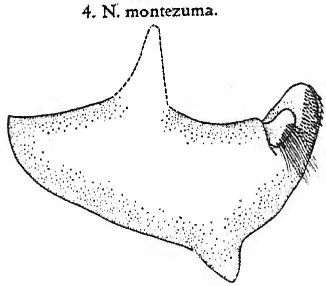
3. N. kirkaldyi



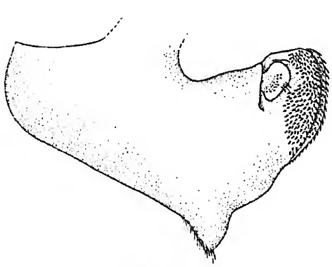
4. N. montezuma.



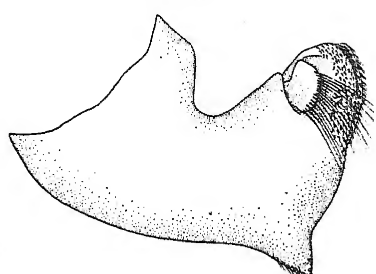
5. N. kiangsis.



6. N. triguttata.



7. N. saramoa.

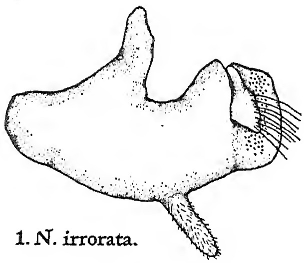


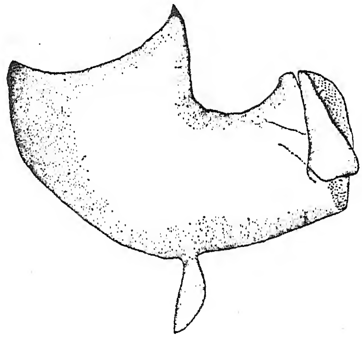
8. N. chinensis.

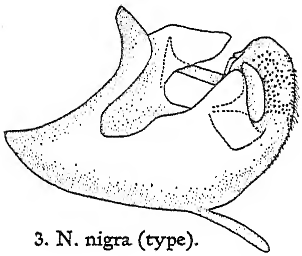
PLATE XVI

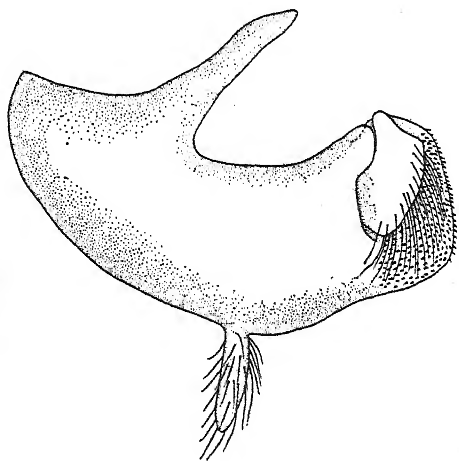
The male genitalia of some Notonecta of the subgenus NOTONECTA. Figures 1 and 2 represent American species, the others are Old World species. In figure 7 the clasper has been drawn out to show its shape.

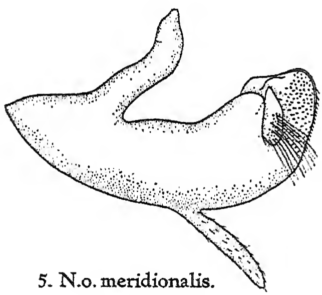
PLATE XVI

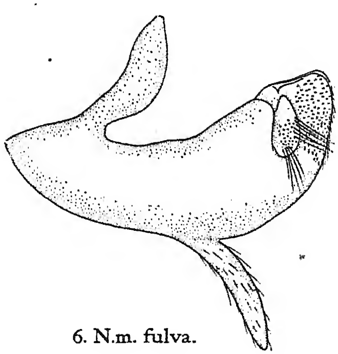

1. N. irrorata.


2. N. borealis.


3. N. nigra (type).


4. N. amplifica.


5. N.o. meridionalis.


6. N.m. fulva.

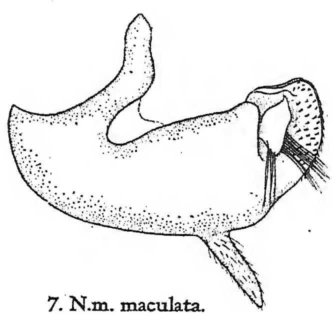

7. N.m. maculata.

PLATE XVII

Male genital capsules of the subgenus Notonecta. (Eastern Hemisphere.)

Figures 1 and 2 are of species related to *N. borealis* Bueno and Hussey, on Plate XVI, figure 2.

Figure 4 shows the acute anterolateral angles of the pronotum. Compare with Plate VIII, figure 8.

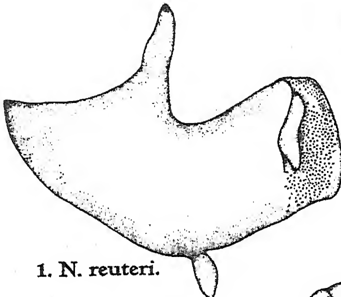
Figures 6 and 11 are oriental species.

Figure 8. The left parameres or claspers of *N. pallidula* Poisson (left) and of *N. maculata* Fabr. (right). (After Poisson.)

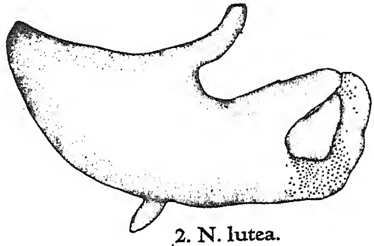
Figure 13. Head and pronotum of *N. maculata* Fabr. (After Poisson.)

Figure 14. Head and pronotum of *N. pallidula* Poisson. (After Poisson.)

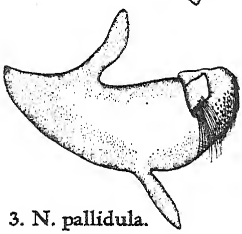
PLATE XVII



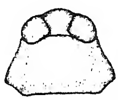
1. N. reuteri.



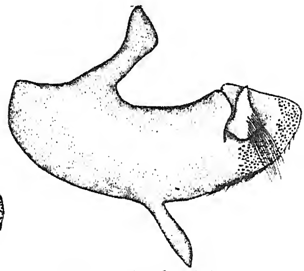
2. N. lutea.



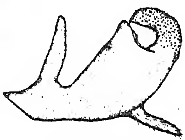
3. N. pallidula.



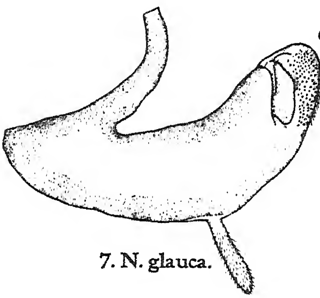
4. N. v. viridis.



5. N. v. kashmiriana.

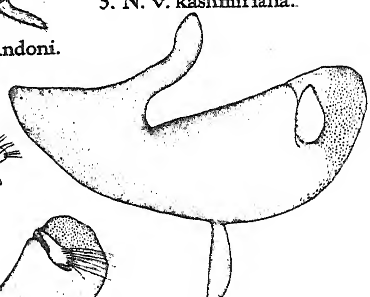


6. N. montandoni.

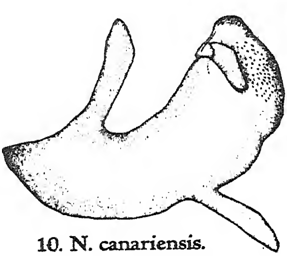


7. N. glauca.

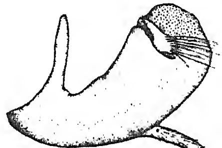
8.



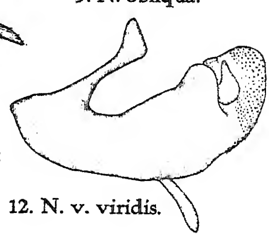
9. N. obliqua.



10. N. canariensis.

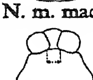


11. N. violacea.



12. N. v. viridis.

13. N. m. maculata.



14. N. pallidula.

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SCIENCE BULLETIN

VOL. XXI.] MARCH, 1933. [No. 2.

The Giant Water Bugs

(Belostomatidæ—Hemiptera)

CARL CUMMINGS, Lawrence, Kansas * †

ABSTRACT: This paper gives the key to the eleven genera of Belostomatidæ and keys to the genera Lethocerus and Diplonychus, together with descriptions of three new species of Lethocerus.

THE giant water bugs have attracted more attention than any of the other aquatic Hemiptera. They have been called "fish killers" and are quite widely known in this country under the name "electric-light bugs." These large insects measure from 40 to 110 mm. in length. They live and develop in ponds and other water bodies, where they feed upon small fish and any other small animals, including insects which they can capture. At night the adults take wing and are attracted to street lights, where because of their large size they command attention.

The family Belostomatidæ comprise, for the most part, large, flat, brown bugs, with hind legs ciliated and flattened for swimming. They bear short, flat, straplike appendages at the tip of the abdomen; these are retractile. The antennæ are hidden in pockets beneath the eyes, and the front legs are raptorial. The family can be divided roughly into the "giant water bugs" and the "toebiters."

* Contribution from the Department of Entomology, University of Kansas.

† It is with deep regret that I must report the untimely death of Carl Cummings two days after he submitted this paper in partial fulfillment for the requirement of the master of arts degree. Mr. Cummings, in company with two other young men, was on a collecting expedition up the Kaw river, when rough water capsized the canoe, and Mr. Cummings, although a strong swimmer, could not overcome the handicap of the heavy clothing he was wearing and went down in thirty feet of water. The death of this promising young man is a real loss to science, because he has demonstrated in this paper an unusual ability to fix upon structural characters of specific value that have been overlooked by former students of this difficult family. To my mind, Mr. Cummings has given us the first satisfactory key to the genus Lethocerus. It was his intention to undertake the study of the genus Belostoma as his next assignment.—H. B. HUNGERFORD.

The former comprise the genera Lethocerus, Benacus, Kirkaldyia and Diplonychus; the latter include the remaining genera. Diplonychus is included, for convenience, in the first group because it contains a species or two of large size. The habit of depositing the eggs on the back of the males, as in Belostoma and Sphærodema, however, really relate it to the second group.

Since there are only one or two species in Benacus and Kirkaldyia, it is necessary only to provide a key for Lethocerus and Diplonychus.

KEY TO GENERA OF BELOSTOMATIDÆ

(Based upon Bueno, Can. Ento., 1907, p. 333, with the addition of *Horvathinia* Montandon and *Kirkaldyia* Montandon)

A. Anterior femora not sulcate.......... *Benacus* Stal. (See p. 200)

AA. Anterior femora sulcate.
- B. Anterior tarsi without claws.......... *Horvathinia* Montandon.
- BB. Anterior tarsi with claws.
  - C. Anterior tarsi with two claws.
    - D. Claws of anterior tarsi of equal length, minute.
      - E. Anterior femora more or less incrassate, much larger than tibiæ.
        - F. Species with two sulci between the eyes.... *Nectocoris* Mayr.
        - FF. Species without such sulci.......... *Sphærodema* Laporte.
      - EE. Anterior femora scarcely incrassate, but little larger than tibiæ.......... *Limnogeton* Mayr.
    - DD. Claws of anterior tarsi of equal or unequal length but elongate. *Diplonychus* Laporte. (See p. 214)
  - CC. Anterior tarsi with one claw.
    - D. Head conically produced, rostrum long, thin.
      - E. Membrane of hemelytra large.......... *Belostoma* Latreille.
      - EE. Membrane of hemelytra much reduced.......... *Abedus* Stal.
    - DD. Head not conically produced, rostrom short, stout.
      - E. Front femur with two unequal sulci for reception of tibia. *Kirkaldyia* Montandon.
      - EE. Front femur with two equal sulci for reception of tibia. *Lethocerus* Mayr. (See p. 198)

KEY TO SPECIES OF LETHOCERUS MAYR (WESTERN HEMISPHERE)

(NOTE.—In this key the interocular space is measured at its narrowest place, and measurements on tibia and tarsus do not include fringe of hair.)

A. Under side of posterior tibia with inner apical angle produced into a sharp point.†
- B. Posterior tibia half as wide as front femur.
  - C. Upper margin of eye straight as viewed from the front.... *L. collosicus* Stal. (See p. 205)
  - CC. Upper margin of eye rounded as viewed from the front.
    - D. Lateral margins of pronotum broadly foliaceous (thin). *L. camposi* Montandon. (See p. 204)

---

† Species from Africa, Madagascar and the Orient belong in this first section. The outer margin of hind tibia is nearly straight in *Lethocerus niloticum* Stal from Africa and in *Lethocerus insulanum* Mont. from New Guinea and New Caledonia, while in *Lethocerus indicus* L. and a species from Madagascar, *L. oculatus* (Mont.), the hind tibia is broader and the outer margin is curved. Montandon has designated a species from Queensland, Australia, under the name *B. edentulum* that is like his *B. insulanum* except it does not have the inner apical angle of the posterior tibia produced into a sharp point.

DD. Lateral margins of pronotum not broadly foliaceous..*L. angustipes* Mayr. (See p. 202)

BB. Posterior tibia at least two-thirds as wide as front femur.

C. Anterior and posterior femora equal in length, median longitudinal fuscous stripe on front of head narrow........................*L. grandis* Linnæus. (p. 208)

CC. Anterior femur longer than posterior femur, median longitudinal fuscous stripe on front of head wide.........................*L. largus* Cummings (p. 210)

AA. Under side of posterior tibia with inner apical angle not produced into a sharp point.

B. Interocular space equal to width of eye.....................*L. americanus* Leidy (p. 201)

BB. Interocular space not over three-fourths width of eye.

C. Interocular space greater than width of hind tarsi.

D. Metaxyphus not sharply pointed posteriorly..... *L. truncatus* sp. nov. (p. 212)

DD. Metaxyphus sharply pointed posteriorly.

E. Two longitudinal fuscous stripes on abdominal venter. *L. annulipes* Herrich-Schaffer. (p. 203)

EE. No fuscous stripes on abdominal venter.

F. Interocular space nearly equal to width of hind tarsus, abdomen tesselate with fuscous spots. *L. mello-leitaoi* De Carlo. (p. 211)

FF. Interocular space one-fifth greater than hind tarsus. Abdomen reddish, not tesselate........*L. uhleri* Montandon. (p. 213)

CC. Interocular space less than width of hind tarsus.

D. Abdomen with fuscous margin, anterior tarsi white..*L. dilatus* sp. nov. (p. 208)

DD. Abdomen without fuscous margin, anterior tarsi not white.

E. Outer margin of hind tibia more curved than inner margin, under surface of tibia mostly light brown...*L. del pontei* De Carlo. (p. 206)

EE. Outer margin of hind tibia no more curved than inner margin, under surface of tibia mostly fuscous....*L. mello-leitaoi* De Carlo. (p. 211)

The Old World species of Lethocerus known to me may be separated by the following key:

A. Under side of posterior tibia with inner apical angle produced into a sharp point.

B. Posterior lobe of pronotum with distinct continuous median longitudinal carina.

C. Width of interocular space in front a little more than ½ transverse diameter of an eye.

D. Divergent yellow lines on anterior lobe of pronotum broad. Eyes elongate, nearly twice as long as wide.................*L. indicus* (L.).

DD. Divergent yellow lines on anterior lobe of pronotum slender. Eyes less elongate, only 1½ times as long as wide. *L. niloticus* (Stal.) and var. *persicus* (Mont.).

CC. Width of interocular space in front less than one-half transverse diameter of an eye. Eyes large ....*L. oculatus* (Mont.).

BB. Posterior lobe of pronotum without a continuous distinct median longitudinal carina ....*L. insulanum* (Mont.).

AA. Under side of posterior tibia with inner apical angle not produced into a sharp spine ....*L. edentulum* (Mont.).

Benacus griseus (Say), 1832

1832. *Belostoma griseus* Say. Heter. New Harmony, p. 37, (Fitch reprint, p. 809). Compl. Writ., I, p. 365.
1863. *Belostoma griseus* (Say) Dufour. Ann. Soc. Ento. Fr., ser. 4, III, p. 400.
1876. *Benacus griseus* (Say) Uhler. Bul. U. S. Geol. Geog. Surv., I, p. 337.
1878. *Benacus griseus* (Say) Uhler. Proc. Bost. Soc. Nat. Hist., XIX, p. 441.
1884. *Benacus griseus* (Say) Uhler. Stand. Nat. Hist., II, p. 256.
1894. *Benacus griseus* (Say) Van Duzee. Bul. Buf. Soc. Nat. Sci., V, p. 185.
1905. *Benacus griseus* (Say) Howard. Insect Book, p. 248, fig. 4.
1905. *Benacus griseus* (Say) Bueno. Jl. N. Y. Ento. Soc., XIII, p. 434.
1907. *Benacus griseus* (Say) Bueno and Brimley. Ento. News, XVIII, p. 434.
1908. *Benacus griseus* (Say) Bueno. Jl. N. Y. Ento. Soc., XVI, p. 237.
1909. *Benacus griseus* (Say) Van Duzee. Bul. Buf. Soc. Nat. Sci., IX, p. 184.
1914. *Benacus griseus* (Say) Barber. Bul. Am. Mus. Nat. Hist., XXXIII, p. 498.
1919. *Benacus griseus* (Say) Hungerford. Sci. Bul. U. of Kans., vol. XI, col. pl. II, fig. 5.
1926. *Benacus griseus* (Say) Blatchley. Het. of East. N. A., p. 1042.

The following also refer to *Benacus griseus* Say:

1847. *Belostoma haldemanus* Leidy. Jl. Acad. Nat. Sci. Phil., ser. 2, I, pp. 59, 66.
1853. *Belostoma impressus* Haldermann. Proc. Acad. Nat. Sci. Phila., VI, p. 364.
1854. *Belostoma harpax* Stal. Of. Vet. Akad. Forh., XI, p. 240.
1856. *Belostoma angustatus* Guerin. Sagra, Hist. de Cuba, VII, p. 176.
1861. *Benacus haldemanus* (Leidy). Stal, Of. Vet. Akad. Forh., XVIII, p. 205.
1863. *Benacus haldemanus* (Leidy). Dufour, Ann. Soc. Ento. Fr., ser. 4, III, p. 363.
1871. *Benacus haldemanus* (Leidy). Mayr, Verh. Zool. Bot. Ges. Wien, XXI, p. 428.

Size. Medium-sized species. Length, 47 mm. to 64 mm.; width, 18.5 mm. to 25 mm.

Shape. Body elongate oval with lateral margins of hemelytra slightly dilated. Pronotum convex, with lateral margins straight.

Color. General color medium brown. Anterior lobe of pronotum fuscous, margined on front and sides with brown; a broad median brown stripe arising on anterior margin and continuing to posterior margin of lobe. Scutellum with large fuscous rectangular area. Hemelytra brown with distal third lighter. Abdomen medium brown. Legs medium brown and unmarked.

Structural Characteristics. Front of head without a longitudinal median carina. Pronotum smooth. Length of first segment of front tarsus equal to second on outer margin. Under side of posterior tibia with inner apical angle not produced into a sharp point. Female operculum minutely bidentate at apex, male operculum not bidentate. Metaxyphus sharply pointed posteriorly. Width of hind tarsus greater than interocular space.

Comparative Notes. This species differs from those of the genus Lethocerus in not having grooves in the front femora for reception of tibiæ.

Types. Are unknown.

Data on Distribution. Kansas: Douglas Co., William Hoffman, July 8, 1920; May 24, 1918; Douglas Co., H. B. Hungerford.

Texas: Galveston, May, F. H. Snow; Sutton Co., 7:16:28, R. H. Beamer. Florida: Palm Beach; Inverness, 8:1:30, Paul W. Oman. Cuba: Rio Almendares, Marinao Prov., Havana, May 24, 1922, P. J. Bermudez; Nov., 1932, P. J. Bermudez.

Lethocerus americanus (Leidy), 1847

1847. *Belostoma americanum* Leidy. J. Acad. Nat. Sci. Phila., VI, pp. 58, 66.
1876. *Belostoma americanum* Leidy. Uhler, Bul. U. S. Geol. Geog. Surv., I, p. 337.
1878. *Belostoma americanum* Leidy. Uhler, Proc. Bost. Soc. Nat. Hist., XIX, p. 441.
1884. *Belostoma americanum* Leidy. Uhler, Stand. Nat. Hist., II, p. 256.
1894. *Belostoma americanum* Leidy. Van Duzee, Bul. Buf. Soc. Nat. Sci., V, p. 185.
1895. *Belostoma americanum* Leidy. Gillette and Baker, Hemip. Colo., p. 63.
1896. *Belostoma americanum* Leidy. Montandon, Ann. Soc. Ent. Belg., XL, p. 512.
1905. *Amorgius americanus* (Leidy). Bueno, Jl. N. Y. Ent. Soc., XIII, p. 44.
1908. *Lethocerus americanus* (Leidy). Bueno, Jl. N. Y. Ent. Soc., XVI, p. 237.
1914. *Lethocerus americanus* (Leidy). Barber, Bul. Am. Mus. Nat. Hist., XXXIII, p. 498.
1914. *Lethocerus americanus* (Leidy). Parshley, Psyche, XXI, p. 140.
1925. *Lethocerus americanus* (Leidy). Comstock, Intr. to Ent., p. 366.
1926. *Lethocerus americanus* (Leidy). Blatchley, Het. of East. N. A., p. 1043.
1928. *Lethocerus americanus* (Leidy). Metcalf & Flint, Dest. Use. Insects, p. 190, fig. 114.

The following also refer to *L. americanus* Leidy:

1861. *Belostoma griseum* Stal. Of. Vet. Akad. Forh., XVIII, p. 206.
1863. *Belostoma litigiosum* Dufour. Ann. Soc. Ent. Fr., ser. 4, III, p. 383.
1863. *Belostoma obscurus* Dufour. Ann. Soc. Ent. Fr., ser. 4, III, p. 383.
1871. *Belostoma griseum* Dufour. Mayr, Verh. Zoöl. Bot. Ges. Wien, XXI, p. 427.
1886. *Belostoma grande* Dimmock. Mass. Fish and Game Comm., p. 69.
1896. *Belostoma obscurum* Dufour. Montandon, Ann. Soc. Ent. Belg., XL, p. 512.
1905. *Amorgius obscurus* (Dufour). Bueno, Jl. N. Y. Ent. Soc., XIII, p. 44.
1905. *Benacus griseus* Say. Howard, Insect Book, p. 266, p. xxix, fig. 36.
1915. *Lethocerus obscurus* (Dufour). Bueno, Psyche, XXII, p. 17.
1926. *Lethocerus obscurus* (Dufour). Blatchley, Het. of East. N. A., p. 1044.

Size. Medium-sized species. Length, 40.5 mm. to 61.5 mm.; width, 16.5 mm. to 24 mm.

Shape. Body elongate oval, with lateral margins of hemelytra slightly dilated. Thorax convex with lateral margins almost straight.

Color. General color medium brown. Pronotum brown with a median pair of light-brown lines arising on anterior margin and extending back about one-third the length of anterior lobe. Scutellum with large fuscous rectangular area. Hemelytra brown with distal third lighter. Abdomen medium brown. Middle and hind femora with three transverse fuscous stripes; front legs and middle and hind tibiæ usually indistinctly marked.

Structural Characteristics. Front of head with indistinct longitudinal median carina. Interocular space at narrowest place about equal to width of eye. First segment of front tarsus in ratio of 10 to 13 to second segment measured on outer margin. Under side of posterior tibia with inner apical angle not produced into a sharp

point. Female operculum with two sharp points at apex; male operculum without points. Metaxyphus sharply pointed posteriorly.

Comparative Notes. This species differs from other species of Lethocerus in having the interocular space at narrowest place equal to width of eye. *L. obscurus* (Dufour) has been applied to small males of *L. americanus* (Leidy) and is not a good species.

Types. Location not known.

Data on Distribution: Michigan: Mich., Chickering, May 3, 1930; Douglas Lake, Bryant Bog, Aug. 3, 1923, and Aug. 17, 1923, H. B. Hungerford; Douglas Lake, Sedge Point Pool, 1932, also July 3, 1923, and July 6, 1923, H. B. Hungerford; Douglas Lake, July 20, 1926, H. B. Hungerford. New York: White Plains, May 14, 1907; West Point, Sept. 11, 1926, W. Robinson; Queens, L. I., F. M. Schott; Ithaca, H. L. Zabristic; Long Island. New Jersey: Brown's Mills, Patterson. Washington, D. C.: Washington, D. C., D. H. Clemons. Wisconsin: Cranmoor, C. W. Hooker. Delaware: Del. Water Gap. Ohio: Geauga Co., Oct. Kansas: Lawrence, F. H. Snow; Harvey Co., Aug. 27, 1917; Lawrence, May 9, 1920, H. B. Hungerford; Lawrence, W. Hoffman. Nevada: Meapa, G. F. Knowlton, April 24, 1923. Utah: Logan, Aug. 15, 1910; May 6, 1910; Nov. 1, 1922; Oct. 11, 1909; Lehi, May 27, 1930; G. F. Knowlton; Vineyard, Tom Spaulding. Oregon: Lost River, Alene. California: Sacramento, April 29, 1908, E. D. Ball; Eureka, H. S. Barber; San José.

Lethocerus angustipes (Mayr), 1871

1871. *Belostoma angustipes* Mayr. Verh. Zoöl.-Bot. Ges. Wien, XXI, p. 427.
1896. *Belostoma angustipes* Mayr. Montandon, Ann. Soc. Ent. Belg., XL, p. 511.
1901. *Belostoma angustipes* Mayr. Champion, Biol. Centr. Am., Heter., II, p. 368, pl. 22, fig. 3.
1909. *Lethocerus angustipes* Mayr. Kirkaldy & Bueno, Proc. Ent. Soc. Wash., X, p. 188.
1917. *Lethocerus angustipes* Mayr. Van Duzee, Cat. of Hemiptera, p. 466.

Size. Medium sized species. Length, 47 mm. to 68 mm.; width, 21.5 mm. to 28 mm.

Shape. Body elongate oval with lateral margins of hemelytra almost parallel. Thorax convex with lateral margins slightly curved.

Color. General color medium brown. Anterior lobe of pronotum fuscous, margined on front and sides with light brown; a median pair of light-brown lines arising on anterior margin and extending back about one-third the length of lobe. Scutellum with large rectangular fuscous area which is divided on front half by a slender

median longitudinal line. Hemelytra brown with distal third lighter. Abdomen mostly fuscous with outer margin light brown. Markings on legs often indistinct, broad fuscous longitudinal streak on upper side of front femur which is nearly immaculate beneath.

Structural Characteristics. Eyes broadly rounded on upper margin. Front of head not medianly carinate. Surface of pronotum smooth, with lateral margins thin at extreme edge, but not broadly foliaceous. Under side of posterior tibia with inner apical angle produced into a sharp point. Width of posterior tibia equal to interocular space at narrowest place, and equal to one-half the width of front femur. Lateral margins of posterior tibia nearly straight. Posterior end of metaxyphus sharply pointed posteriorly, with anterior end not abruptly elevated into a point. Apex of female operculum feebly bidentate, male operculum not bidentate.

Comparative Notes. This species differs from *L. camposi* Montandon in being smaller and in having the lateral margins of the pronotum not foliaceous, and from *L. niloticum* Stal and *L. insulanum* Montandon in having the hind tibia equal to the interocular space.

Types. Doctor Hungerford says there are specimens in the Museum at Vienna, evidently studied by Mayr.

Data on Distribution. United States: Death Valley, Nev., T S Galmer. Mexico; Durango, Dr. E. Palmer; Mex. R. Muller; Zitacuaro, Michoacan, 8-5-1932; Dist. Fed., por Ancona; Colima.

Lethocerus annulipes (Herrich-Schaffer), 1846

1846. *Belostoma annulipes* H.-S. Wanz. Ins., VIII, p. 28, figs. 803, 804.
1865. *Belostoma annulipes* H.-S. Mayr, Hemip., pp. 185, 186.
1871. *Belostoma annulipes* H.-S. Mayr, Verh. Zoöl. Bot. Ges. Wien, XXI, p. 427.
1930. *Lethocerus annulipes* H.-S. De Carlo, Rev. de la Soc. Ent. Arg., p. 107, pl. VI, figs. 21 and 23.

The following also refer to *L. annulipes* H.-S.:

1863. *Belostoma reficeps* Dufour. Ann. Soc. Ent. Fr., ser. 4, III, p. 382 (?).
1863. *Belostoma signoreti* Dufour. Ann. Soc. Ent. Fr., ser. 4, III, p. 382 (?).
1863. *Belostoma distinctum* Dufour. Ann. Soc. Ent. Fr., ser. 4, III, p. 382 (?).
1896. *Belostoma mayri* Montandon. Ann. Soc. Ent. Belg., XL, p. 514.

Size. Medium-sized species. Maximum length, 75 mm.; maximum width, 26½ mm.; minimum length, 53 mm.; minimum width, 21 mm.

Shape. Body elongate oval with lateral margins of hemelytra nearly parallel. Thorax convex with lateral margins distinctly curved.

Color. General color medium brown. Pronotum brown with a

median pair of light-brown lines arising on anterior margin and extending back about one-third the length of anterior lobe. Scutellum with large fuscous rectangular area. Hemelytra brown with distal third lighter. Abdomen light brown; a pair of fuscous stripes beginning on the anterior margin of second segment and ending on sixth. Middle and posterior tibiæ and femora each with three transverse fuscous stripes on ventral side. Front legs indistinctly marked.

Structural Characteristics. Front of head without a longitudinal median carina. Pronotum smooth. Width of interocular space at narrowest place is greater than width of hind tarsus. Length of first segment of front tarsus one-half that of second on outer margin. Underside of posterior tibia with inner apical angle not produced into a sharp point. Female operculum minutely bidentate at apex, male operculum not bidentate. Metaxyphus sharply pointed posteriorly.

Comparative Notes. This species differs from other species of Lethocerus in having two longitudinal fuscous stripes on lower side of abdomen.

Types. Described from South America, location of type unknown.

Data on Distribution. United States: Palm Beach, Florida (W. Robinson bequest). Brazil: Ypirango, S. Paulo, S. A., Rbt. Spitz, 1-20-26, 1-27-24, 2-7-24; St. Catharina; Buenos Ar. Rep., Arja, Brazil, S. A., Alfredo Faz, 1921; Brazil, E. C. Green. Argentina: Icano-Rio Salado, Santiago del Estero, S. A., Fives Lille, Santa Fé, A. Bruch, 1923; Bs. Aires, C. S. Reed; Buenos Aires, Argentine Republic, S. A., H. T. Martin. British Guiana: Plantation Ecceles, E. Bank Demerara River, S. Harris, 4-4-32. French Guiana: St. Laurent, Guyana. Paraguay: Villarrica, Paraguay, S. A., Fran. Schade, 10-29-29, 9-10-23. Colombia: Colombia, S. A. Venezuela: Caracas, H. Pittier. Porto Rico: Porto Rico, E. A. Wagerrin.

Lethocerus camposi (Montandon), 1900

1900. *Amorgius camposi* Montandon. Bul. de la Soc. des Sci. de Buc., p. 561.

Size. Large species. Length, 77 mm. to 85 mm.; width, 30 mm. to 32 mm.

Shape. Body elongate oval with lateral margins of hemelytra almost parallel. Pronotum convex with lateral margins curved.

Color. General color medium brown. Anterior lobe of pronotum fuscous, margined on front and sides with brown; a median pair of brown lines arising on anterior margin and extending back about

one-third the length of lobe; a pair of conspicuous brown oval spots. Scutellum with large rectangular fuscous area. Hemelytra brown with distal third lighter. Abdomen brown with margin lighter and tesselate with fuscous spots. Middle and hind femora with three transverse fuscous stripes on ventral side; legs otherwise not distinctly marked.

Structural Characteristics. Eyes broadly rounded on upper margin. Front of head with longitudinal median carina. Lateral margins of pronotum broadly foliaceous; posterior lobe rugose, anterior lobe rough, but not rugose. Underside of posterior tibia with inner apical angle produced into a sharp point. Width of posterior tibia less than half that of anterior femur. Lateral margins of hind tibia nearly straight. Metaxyphus sharply pointed posteriorly with anterior end not abruptly elevated into a point. Apex of female operculum feebly bidentate, male operculum not bidentate at apex.

Comparative Notes. This species differs from *L. collosicus* Stal in being lighter in color and in having the upper margin of eye rounded; *L. niloticum* Stal, *L. insulanum* Montandon, and *L. angustipes* Mayr in having the lateral margins of pronotum broadly foliaceous.

Types. Described from Guayaquil, Ecuador. In Montandon's collection, Bucharest.

Data on Distribution. Ecuador: Guayaquil, Duran, F. Campos, (Specimen compared with cotype); Guayaquil, F. W. Goding; Guayaquil, F. Campos.

Lethocerus collosicus (Stal), 1854

1854. *Belostoma collosicus* Stal. Ofv. Vet.-Ak. Forh., XI, p. 239.
1861. *Belostoma collossicum* Stal. Ofv. Vet.-Ak. Forh., XVIII, p. 205.
1863. *Belostoma colossicum* Stal. Dufour, Ann. Soc. Ent. Fr., ser. 4, III, 381.
1865. *Belostoma colossicum* Stal. Mayr, Hemiptera, p. 184.
1871. *Belostoma colossicum* Stal. Mayr, Verh. Zoöl.-Bot. Ges. Wien, XXI, pp. 423, 425.
1884. *Belostoma collosicum* Stal. Uhler, Stand. Nat. Hist., II, p. 256.
1895. *Belostoma colossicum* Stal. Mont., Ann. Soc. Ent. Belg., pp. 472-477, fig. 2.
1901. *Belostoma colossicum* Stal. Champion, Biol. C.-Am., Hem.-Het., II, pl. 22, fig. 4.
1906. *Amorgius colossicum* (Stal). Bueno, Ent. News, Feb., p. 55.
1909—*Lethocerus colossicus* (Stal). Kirkaldy and Bueno, Proc. Ent. Soc. Wash., X, p. 188.

Size. Large species. Length, 72 mm.-85 mm.; width, 31 mm.-34 mm.

Shape. Body elongate oval with lateral margins of hemelytra somewhat dilated. Head, short, as seen from above. Thorax convex with lateral margins widely rounded.

Color. General color nearly black. Lateral margins of hemelytra coarsely tesselate with light brown. Median and posterior

tibiæ and femora each with two narrow transverse light-brown stripes.

Structural Characteristics. Front of head with a longitudinal median carina. Eyes triangular in appearance when viewed from the front, with upper margin of eye straight. Pronotum rugose with lateral margins broadly foliaceous (thin). Underside of posterior tibia with inner apical angle produced into a sharp point. Front femur more than twice as wide as hind tibia, which has its lateral margins almost straight. Metaxyphus sharply pointed posteriorly, with anterior end not abruptly elevated into a point. Posterior end of female operculum minutely bidentate at apex, male operculum not bidentate at apex.

Comparative Notes. This species differs from *L. camposi* Montandon in being darker in color and in having the upper margin of eye straight.

Types. Types in collection of Signoret.

Data on Distribution. Cuba: Santiago, Cuba; Cuba, Nov. 1932, P. J. Bermudez; Central San Antonio, Madruga, Prov. Havana, Cuba, P. J. Bermudez, 6-8-32. Mexico: Campeche, E. P. Creaser; Mexico, W. T. M'Donald. Yucatan: Yucatan, E. P. Creaser. Jamaica: Jamaica, J. H. Andrews. Panama: Panama, J. W. Green.

Lethocerus del pontei De Carlo, 1930

1930. *Lethocerus del pontei* De Carlo. Rev. de la Soc. Ent. Arg., No. 13, p. 108, pl. VII, fig. 24.

1932. *Lethocerus del pontei* De Carlo. Rev. de la Soc. Ent. Arg., No. 3, p. 217.

The following also refer to *Lethocerus del pontei* De Carlo:

1876. *Belostoma annulipes* H.-S. Uhler, Bul. U. S. Geol. Geog. Surv., I, p. 337.

1894. *Belostoma annulipes* H.-S. Uhler, Proc. Cal. Acad. Sci., ser. 2, IV, p. 291.

1895. *Belostoma annulipes* H.-S. Gillete and Baker, Hemip. Colo., p. 63.

1896. *Belostoma annulipes* H.-S. Montandon, Ann. Soc. Ent. Belg., XL, p. 516.

1901. *Belostoma annulipes* H.-S. Champion, Biol. Centr. Am., Heter., II, p. 367, pl. 22, fig. 3.

1906. *Amorgius annulipes* H.-S. Bueno, Ent. News. Feb., p. 55.

Size. Medium-sized species. Maximum length, 71 mm., maximum width, 27½ mm.; minimum length, 52 mm., minimum width, 21 mm.

Shape. Body elongate oval with lateral margins of hemelytra slightly dilated. Pronotum convex with lateral margins nearly straight.

Color. General color medium brown. Pronotum brown with lateral margins lighter; a median pair of light-brown lines arising on anterior margin and extending back about one-third the length of anterior lobe. Scutellum with large fuscous rectangular area.

Hemelytra brown with distal third lighter. Abdomen reddish-brown, thinly tesselate with fuscous spots. Mesosternum with large, irregular fuscous spot on midline, fuscous markings not prominent on either side of midline. Anterior tibia with three transverse fuscous stripes on both sides; middle and posterior femora and tibiæ with three transverse fuscous stripes on lower side; markings on legs often indistinct or absent.

Structural Characteristics. Front of head without a longitudinal median carina. Pronotum smooth. Width of eye nearly twice that of interocular space which is not as wide as hind tarsus. Length of first segment of front tarsus one-half that of second on outer margin. Underside of posterior tibia with inner apical angle not produced into a sharp point. Female operculum with two sharp points at apex, male operculum without points. Metaxyphus sharply pointed posteriorly. Outer margin of hind tibia more curved than inner margin.

Comparative Notes. This species differs from *L. dilatus* Cummings in having the outer margin of the abdomen not fuscous, and from *L. mello-leitaoi* De Carlo in having different color markings on lower side and in having outer margin of hind tibia more curved than inner margin.

Types. National Museum of Natural History, Buenos Aires. Holotype from Argentina.

Data on Distribution. Arizona: Santa Cruz Co., 8-4-1927, L. D. Anderson; Patagonia, 8-4-27, R. H. Beamer; Chiricahua Mts., 7-8-32, R. H. Beamer; S. W. edge Tuscon, 7-20-32, R. H. Beamer; Nagales. Texas: Jim Wells Co., 7-24-28, R. H. Beamer; Valentine, July 13, 1927, R. H. Beamer; Victoria, J. D. Mitchell; Brownsville. Cuba: Rio A'mendares, Marinao Prov. Havana, May 24, 1932, P. J. Bermudez. Havana, Cuba, Palmer and Riley; Guantanamo. Jamaica: Alligator Pond, Jamaica; Claremont, E. Perkins. Porto Rico: San Juan. San Salvador: San Salvador, C. Caderon. Costa Rica: Costa Rica, Heinrich Schmidt, 1931. Honduras: Honduras, F. H. Dyer. Panama: Panama. Mexico: Yucatan, G. F. Gaumer; 50 m. S. Victorias, San Luis Potosi, 6-10-32, Hobart Smith; Colima, Encero Vera Cruz, S. of Jalapa, 7-17-32, H. Smith; Mexico, A. Duges; Cordoba, Fred Knab. Ecuador: Guayaquil, W. F. Goding; Guayaquil, F. Campos. Paraguay: Villarrica, S. A., 1-6-24, Fran. Schade; Villarrica, 4-11-23, Fran. Schade. Brazil: Ypirango, S. Paulo, R. Spitz, 1-20-26; Blumenau, Espir Santo.

Lethocerus dilatus sp. nov.

Size. Large species. Length, 74 mm.-85 mm., width, 29.5 mm.-31.5 mm.

Shape. Body elongate oval with lateral margins of hemelytra dilated. Pronotum comparatively small, convex, and with lateral margins straight.

Color. General color medium brown. Anterior lobe of pronotum dark without a pair of light-brown lines arising on anterior margin. Scutellum with large fuscous rectangular area. Hemelytra uniform medium brown throughout. Abdomen medium brown with outer margin fuscous. Anterior tibia fuscous with tarsus white, middle and posterior femora and tibiæ with three transverse fuscous stripes on lower side.

Structural Characteristics. Front of head without a longitudinal medium carina. Anterior lobe of pronotum rough, but not rugose. Width of eye twice that of interocular space which is not as wide as hind tarsus. Length of first segment of front tarsus one-half that of second on outer margin. Underside of posterior tibia with inner apical angle not produced into a sharp point. Female operculum minutely bidentate at apex, male operculum not bidentate. Metaxyphus sharply pointed posteriorly. Outer margin of hind tibia more curved than inner margin.

Comparative Notes. This species differs from *L. del pontei* De Carlo and *L. mello-leitaoi* De Carlo in having the outer margin of the abdomen fuscous on lower side.

Types. In Francis Huntington Snow Entomological Museum of the University of Kansas, holotype ♀ and one paratype ♀.

Data on Distribution. Bolivia: Buena Vista, Dept. Santa Cruz S. A., 9-24-1924, R. T. Steinbach.

Lethocerus grandis (Linnæus), 1758

1758. *Nepa grandis* Linn. Syst. Nat., Ed. x, p. 440.
1794. *Nepa grandis* Linn. Fabricius, Ent. Syst., IV, p. 61.
1803. *Nepa grandis* Linn. Fabricius, Syst. Rhyn., p. 106.
1835. *Belostomum grande* (Linn.). Burmeister, Handb. der Ent., II, p. 195.
1847. *Belostomum grande* (Linn.). Leidy, J. Acad. Nat. Sci. Phil., VI, pp. 58, 66.
1856. *Belostoma grande* (Linn.). Guérin, Sagra, Hist. de Cuba, VII, p. 175.
1863. *Nepa grandis* Linn. Dufour, Ann. Soc. Ent. Fr., ser. 4, III, p. 380.
1871. *Belostoma grande* (Linn.). Mayr, Verh. Zoöl.-Bot. Ges. Wien., XXI, pp. 423, 425.
1865. *Belostoma grande* (Linn.). Mayr, Hemiptera, p. 184.
1884. *Belostoma grandis* (Linn.). Uhler, Stand. Nat. Hist., II, p. 256.
1930. *Lethocerus grandis* (Linn.). De Carlo, Rev. de la Soc. Ent. Arg., No. 13, p. 105, pl. VI, fig. 22.

Size. Largest species of the genus Lethocerus and also of the hemiptera. Length, 94 mm.-110 mm.; width, 34 mm.-40 mm.

Shape. Body elongate oval with lateral margins of hemelytra almost parallel. Thorax convex with lateral margins curved.

Color. General color medium brown. Front of head with a narrow fuscous stripe reaching from vertex to clypeus. Anterior lobe of pronotum fuscous margined on front and sides with brown; a medium pair of brown lines arising on anterior margin, diverging on their posterior third and ending about the middle of the lobe; a pair of conspicuous brown, oval spots in front of which are indefinite brown markings. Scutellum with large rectangular fuscous area. Hemelytra brown with distal third lighter, and with light-brown maculations throughout. Abdominal venter fuscous, fading out to light brown at apex. Underside of all tibiæ and femora each with three broad, transverse fuscous bands.

Structural Characteristics. Eyes large and broadly rounded on upper margin. Front of head not medianly carinate. Surface of pronotum smooth, lateral margins moderately explanate and edges thickened, not foliaceous. Underside of posterior tibia with inner apical angle produced into a sharp point. Width of posterior tibia at least two-thirds that of anterior femur. Length of anterior femur equal to hind femur. Outer margin of hind tibia curved and inner margin nearly straight. Metaxyphus sharply pointed posteriorly, with anterior end abruptly elevated into a point. Apex of female operculum with two sharp points, male operculum without points.

Comparative Notes. This species differs from *L. largus* Cummings in having the front and hind femora equal, and in having different color markings on face and abdomen.

Type. Doctor Hungerford says there are some twenty-six trays of insects in the Museum at Upsala, Sweden, that are supposed to have been studied by Linnæus. There is a specimen of Lethocerus measuring 83 mm. long bearing the following labels "Mus. Gust. Adolphi" "typus" *"Nepa grandis"* and another only 38 mm. long labeled *"Nepa grandis?"* "C. U. Mus. Gust. Adolphi" "Grandis β." Linnæus, in his 10th ed. of Systema Naturæ, list his specimen from "M. L. U." and gives three references to literature. Since Gust. Adolphus was a small boy in 1758 it may be that the specimen labeled "typus" is not the type, and therefore it seems best to let the species described above and also recognized by Mr. de Carlo stand as *Lethocerus grandis* (Linn.).

Data on Distribution. Brazil: Igarape Assu, 1912. Paraguay: Villarica, 8, 31, Fr. Schade. Colombia: Villavicencio, Ost. Colombia, 400 m, coll. Fassl.

Lethocerus largus sp. nov.

Size. Large species, second in size only to *L. grandis* Linnæus. Length, 84 mm. to 94 mm.; width, 30 mm. to 33 mm.

Shape. Body elongate oval with lateral margins of hemelytra almost parallel. Pronotum convex with lateral margins curved.

Color. General color medium brown. Front of head with broad fuscous stripe reaching from vertex to clypeus. Anterior lobe of pronotum fuscous, margined on front and sides with light brown; a median pair of brown lines arising on anterior margin, diverging on their posterior third and ending about the middle of lobe; a pair of conspicuous brown, oval spots, in front of which are indefinite brown markings. Scutellum with large rectangular fuscous area. Hemelytra brown with distal third lighter, and without light-brown maculations. Abdomen fuscous with outer margin light brown. Front legs not transversely marked, middle and hind tibiæ and femora each with three broad, transverse, fuscous bands on lower side.

Structural Characteristics. Eyes large and broadly rounded on upper margin. Front of head not medianly carinate. Surface of pronotum smooth, lateral margins moderately explanate and edges thickened, not foliaceous. Underside of posterior tibia with inner apical angle produced into a sharp point. Width of posterior tibia at least two-thirds that of anterior femur. Length of anterior femur greater than that of hind femur. Outer margin of hind tibia curved and inner margin nearly straight. Metaxyphus sharply pointed posteriorly, with anterior end abruptly elevated into a point. Apex of female operculum with two sharp points, male operculum without points.

Comparative Notes. This species differs from *L. grandis* (Linnæus) in having the front femora longer than hind femora and in having different color markings on face and abdomen.

Types. Francis Huntington Snow Entomological Collection of University of Kansas, ♂ holotype, and ♀ allotype.

Data on Distribution. Brazil: Ypirango, S. A., S. Paulo, 2-7-24, R. Spitz; Sao Paulo, Brazil, S. A., 1922, Alfredo Faz; S. Paulo, Brazil.

Lethocerus mello-leitaoi de Carlo, 1933

1933. *Lethocerus mello-leitaoi* de Carlo. Boletim do Museu Nacional, Vol. IX, N. 1, pp. 93-95.

Original description has not been printed at the date of this writing.

Size. Medium-sized species. Length, 60 mm.-71 mm.; width, 22.5 mm.-27 mm.

Shape. Body elongate oval with lateral margins of hemelytra nearly straight. Pronotum convex with lateral margins slightly curved.

Color. General color medium brown. Pronotum brown, a median pair of light-brown lines arising on anterior margin and extending back about one-third the length of anterior lobe. Scutellum with large fuscous rectangular area. Hemelytra brown with distal third lighter. Abdomen light brown and thickly tesselate with fuscous spots. Mesosternum with large irregular fuscous spot on midline, and large irregular fuscous markings on either side of median spot. Front legs not marked, middle and hind femora each with three broad transverse fuscous stripes on ventral side; middle and hind tibiæ almost entirely fuscous on ventral side.

Structural Characteristics. Front of head without a longitudinal median carina. Pronotum slightly rough, but not rugose. Width of interocular space about two-thirds width of eye. Interocular space is about equal to width of hind tarsus. Length of first segment of front tarsus one-half that of second on outer margin. Underside of posterior tibia with inner apical angle not produced into a sharp point. Female operculum with two sharp points at apex, male operculum without points. Metaxyphus sharply pointed posteriorly. Outer margin of hind tibia no more curved than inner margin.

Comparative Notes. This species differs from *L. uhleri* Montandon in having the interocular space about equal to width of hind tibia, and from *L. del pontei* de Carlo in having the outer margin of hind tibia no more curved than inner margin, and in having different color markings on lower side of abdomen, tibia, and mesosternum.

Types. Holotype male and allotype female in Francis Huntington Snow collection of the University of Kansas. One paratype in National Museum of Natural History, Buenos Aires.

Data on Distribution. Brazil: St. Catharina; Blumenau, Brazil. Paraguay: Villarica, 1931, Fr. Schade.

Lethocerus truncatus sp. nov.*

Size. Medium-sized species. Length, 74 mm.; width, 28.5 mm.

Shape. Body elongate oval with lateral margins of hemelytra slightly dilated. Pronotum convex with lateral margins slightly curved.

Color. General color medium brown. Anterior lobe of pronotum slightly darker than posterior lobe, with no distinct markings present. Scutellum medium brown. Hemelytra of uniform medium tan throughout. Under surface of a uniform medium tan throughout. Middle and hind femora each with three transverse fuscous bands on lower side.

Structural Characteristics. Front of head without a longitudinal median carina. Pronotum smooth. Width of interocular space is greater than that of hind tarsus and is equal to three-fourths width of eye. Length of first segment of front tarsus two-thirds that of second on outer margin. Underside of posterior tibia with inner apical angle not produced into a sharp point. Female operculum minutely bidentate at apex. Metaxyphus with posterior margin straight and not pointed. Lateral margins of posterior tibia nearly straight.

Comparative Notes. This species differs from all other species of Lethocerus in having the posterior end of metaxyphus not pointed.

Types. In Francis Huntington Snow Entomological Collection of the University of Kansas (single specimen, holotype female).

Data on Distribution. Argentina: Argentina, S. A., Fives Lille, Santa Fé, 1923, A. Bruch.

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* Since Mr. Cummings died I have received a paper by Mr. José A. de Carlo in which he describes a specimen taken by Mr. Carlos Bruch from State of Paraná, Brazil, under the name *L. bruchi.* His single specimen is a male 67 mm. long and 26 mm. wide. The description is published in "Revista de la Sociedad Entomologica Argentina (No. 4, Julio 31 de 1931)" pp. 217-218 and photograph. The description fits Mr. Cummings' species very well. Mr. de Carlo does not mention the unusual shape of the metaxyphus described by Cummings so for the present I permit the species to stand.—H. B. Hungerford.

Lethocerus uhleri (Montandon), 1896

1896. *Belostoma uhleri* Mont. Ann. Soc. Ent. Belg., XL, p. 513.
1905. *Belostoma uhleri* Mont. Howard, Insect Book, pl. 29, fig. 25.
1907. *Belostoma uhleri* Mont. Bueno and Brimley, Ent. News, XVIII, p. 434.
1909. *Amorgius uhleri* (Mont.). Van Duzee, Bul. Buf. Soc. Nat. Sci., IX, p. 184.
1914. *Amorgius uhleri* (Mont.). Barber, Bul. Am. Mus. Nat. Hist., XXXIII, p. 498.
1926. *Lethocerus uhleri* (Mont.). Blatchley, Het. of East. N. A., p. 1043.

The following also refer to *Lethocerus uhleri* Montandon:

1876. *Belostoma americanum* Uhler. Bul. U. S. Geol. Geog. Surv., I, pl. 21, fig. 38. 1876.

Size. Small species. Maximum length, 53 mm., maximum width, 18½ mm.; minimum length, 40 mm., minimum width, 14½ mm.

Shape. Body elongate oval with lateral margins of hemelytra almost parallel. Thorax convex with lateral margins slightly curved.

Color. General color medium brown. Pronotum brown with a median pair of light-brown lines arising on anterior margin and extending back about one-third the length of anterior lobe. Scutellum with large fuscous rectangular area. Hemelytra brown with distal third lighter. Abdomen light tan. Middle and posterior tibiæ and femora each with three transverse fuscous stripes on ventral side. Front legs indistinctly marked.

Structural Characteristics. Front of head not medianly carinate. Interocular space equal to two-thirds width of eye. Length of first segment of front tarsus one-half that of second on outer margin. Interocular space one-fifth greater than the width of hind tarsus. Underside of posterior tibia with inner apical angle not produced into a sharp point. Female operculum with two sharp points at apex; male operculum without points. Metaxyphus sharply pointed posteriorly.

Comparative Notes. This species differs from *L. melloleitaoi* de Carlo and *L. del pontei* de Carlo in being smaller and in having the interocular space one-fifth greater than width of hind tarsus.

Data on Distribution. Massachusetts: Sanborn. Georgia: Waycross, 11-9-09. Kansas: Douglas Co., May, H. B. Hungerford; Douglas Co., July; Douglas Co., May 21, 1920, H. B. Hungerford; Douglas Co., W. Hoffman, May 21, 1919; Riley Co. Florida: Archer, R. H. Beamer, 7-31-30; Vero Beach, E. M. Becton, Sept. 26, 1927. Louisiana: New Orleans, Chickering, 4-30-28. Texas: Colorado Co., Mrs. Grace Wiley, 5-6-1922, 5-10-22; Galveston, F. H. Snow, May. Mexico: Metamoras, J. L. Leconte.

KEY TO SPECIES OF DIPLONYCHUS

There are evidently some undescribed species of this genus which need further study. Mr. Bueno has given the following table for separating the species:

A. Anterior tarsus furnished with two claws of equal length.............*D. rectus* Mayr. (W. Africa.)

AA. Anterior tarsus furnished with two claws of unequal length.

- B. Disk of prothorax punctate, with two pronounced round foveæ, hemelytra more or less punctate..*D. punctatus* Stal. (Madagascar.)
- BB. Disk of prothorax slightly punctate, with two shallow foveæ and two sulci converging posteriorly toward the transverse sulcus, hemelytra impunctate. *D. columbiæ* Spinola. (Africa.)

Mr. Bueno gives *D. columbiœ* as from Africa and questions western records. Doctor Hungerford, who examined the specimens in the Museum at Vienna, says: "Under *Hydrocyrius columbiœ* Spin. there are 19 specimens from Africa and two others, one labeled "C. Amer. Ca 884" and the other "Mex. Coll. Sign." "herculeus det. Dufour." "Columbiæ det. Mayr." These two are the same as those from Dutch East Africa. They have two claws on front tarsus and are 75 mm. long. The outer claw is a little more than half as long as the other.

PLATE XVIII*

FIG. 1. *Lethocerus delpontei* de Carlo. Under side of posterior tibia and tarsus. It illustrates "the posterior tibia with the inner apical angle not produced into a sharp point." Compare with figure 6.

FIG. 2. *Lethocerus* sp. Drawn to show "upper margin of eye rounded as viewed from the front."

FIG. 3. *Lethocerus* sp. Drawn to show "upper margin of eye straight as viewed from the front."

FIG. 4. *Lethocerus truncatus.* The metaxyphus distinguishes this species from the others which are like figure 5.

FIG. 5. *Lethocerus angustipes.* The metaxyphus is of usual form.

FIG. 6. *Lethocerus angustipes.* Under side of posterior tibia and tarsus. It illustrates "the posterior tibia with the inner apical angle produced into a sharp point.

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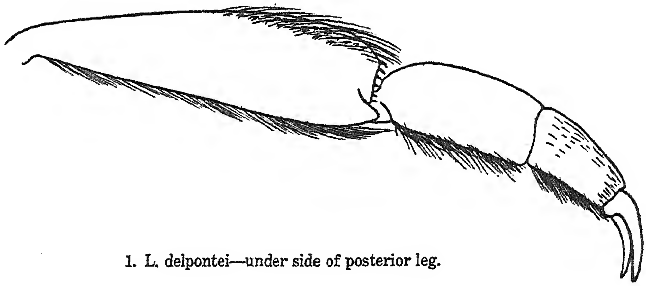
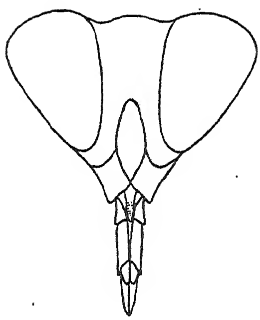
* The drawings of this plate were prepared for me by Dr. Kathleen Doering.—H. B. HUNGERFORD.

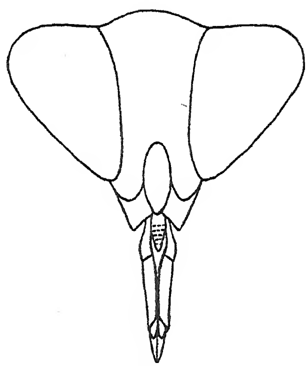
PLATE XVIII



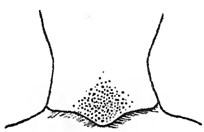
1. L. delpontei—under side of posterior leg.



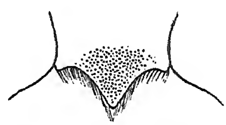
2. Head—eyes rounded.



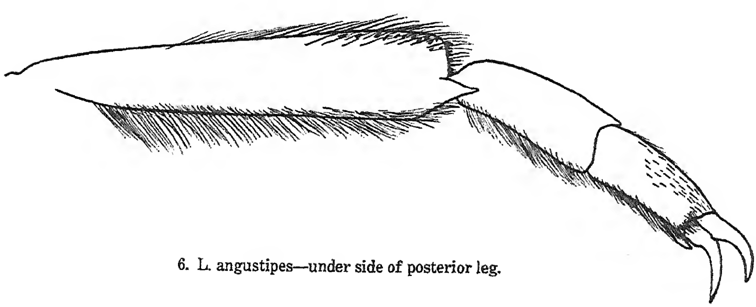
3. Head—eyes straight.



4. L. truncatus—metaxyphus.



5. L. angustipes—metaxyphus.

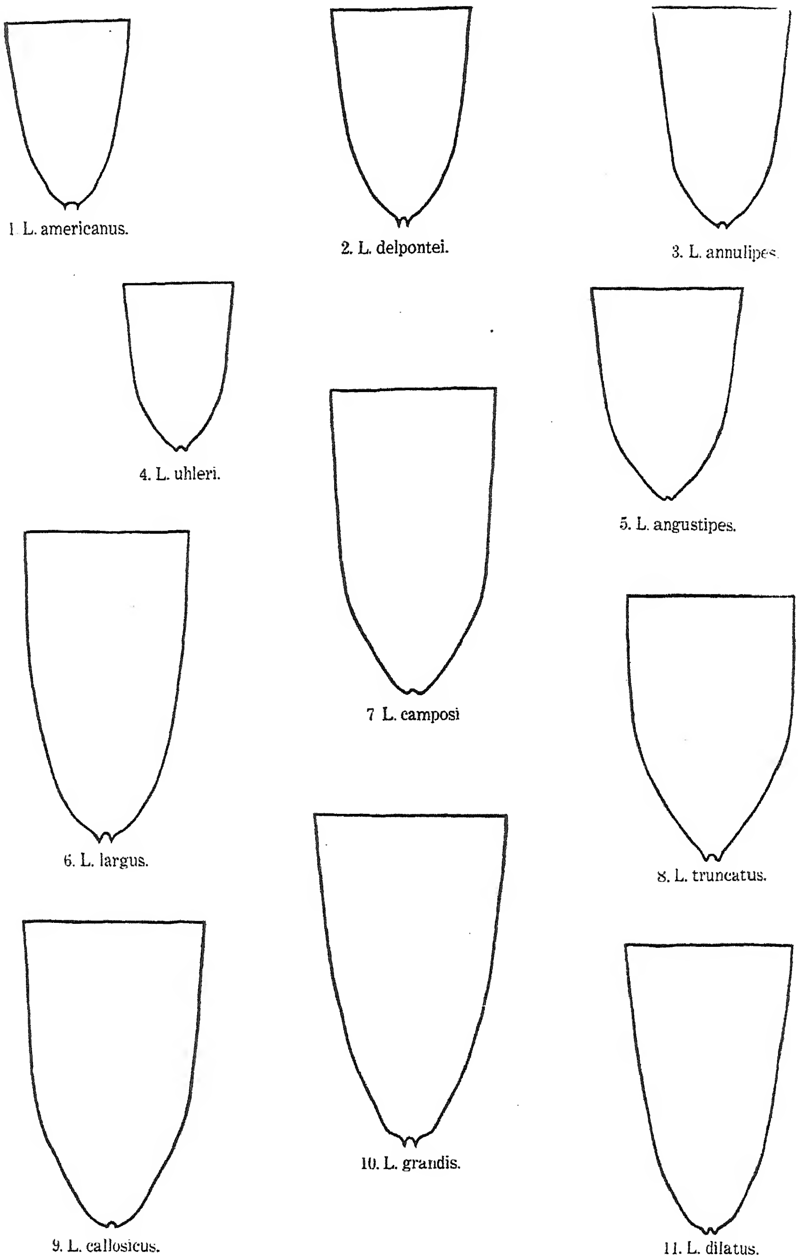


6. L. angustipes—under side of posterior leg.

PLATE XIX

The drawings on this plate illustrate the shape of the last ventral abdominal segment of females of Lethocerus.

PLATE XIX



1. L. americanus.
2. L. delpontei.
3. L. annulipes.
4. L. uhleri.
5. L. angustipes.
6. L. largus.
7. L. camposi
8. L. truncatus.
9. L. callosicus.
10. L. grandis.
11. L. dilatus.

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A Study of the Genus *Brachymetra*

(Hemiptera—Gerridæ)

J. GILBERT SHAW, Lawrence, Kansas*

ABSTRACT: This paper gives a key for separation of five species and one subspecies. Three species and the subspecies are described as new.

THE family Gerridæ is divided into two subfamilies—the Gerrinæ and the Halobatinæ. Among the numerous genera of the latter belongs the genus Brachymetra, a new world genus.

DESCRIPTION OF THE GENUS

All members of the genus Brachymetra possess a triangular and convex head. The almost oval eyes extend obliquely laterad of anterior angles of the pronotum. The rostrum extends well beyond anterior coxæ. The antennæ are over one-half the length of the body, all segments round and straight except the basal, which is definitely arched, basal segment longer than the head, second segment shorter than the head, third segment invariably longer than the second segment, and apical segment of about same length as second. Pronotum possesses medially near anterior margin a shallow horseshoe-shaped impression; single faint carination runs obliquely and posteriorly of each humeral angle. Lateral margins of mesothorax strongly divergent in both sexes. The prothoracic legs are shorter than the body and have rather stout femora, which bear a few stout hairs beneath, while the meso- and metathoracic legs are very long and slender with the frail femora alone about as long and longer, respectively, than the body. The elytra exceed the abdomen.

* Contribution from the Department of Entomology, University of Kansas.

Abdomen moderately short, sixth segment unarmed, apical margin on ventral side of male emarginate, while that of female is almost straight. Claspers inserted on each side of genital capsule of male. Body covered by a dull pubescence. All the species possess on meso- and metathoracic acetabula a heavier pubescence, which is generally silvery.

KEY TO THE SPECIES OF BRACHYMETRA

A. Species with first antennal segment as long or longer than the two following; pronotum striped with black.
  - B. Pronotum with median line black .... *unca* sp. n.
  - BB. Pronotum median line not black but bordered by a pair of black bands. *vittata* sp. n.

AA. Species with first antennal segment shorter than the two following; pronotum, except margin, more or less unicolorous.
  - B. Apex of pronotum acutely angulate, extending well beyond tip of mesothoracic acetabula .... *kleopatra* Kirk.
  - BB. Apex of pronotum rather bluntly angulate, not extending beyond tip of mesothoracic acetabula.
    - C. Anterior femur only slightly larger than intermediate femur; rear margin of eye definitely greater than interocular space .... *lata* sp. n.
    - CC. Anterior femur at least one and one-half times larger than intermediate femur; rear margin of eye equal to or less than interocular space.
      - D. First antennal segment plainly surpassing rear lateral margin of eye when turned back; first abdominal tergite shallowly incised behind .... *albinerva* (A. & S.).
      - DD. First antennal segment just about attaining rear lateral margin of eye when turned back; first abdominal tergite deeply incised behind .... *albinerva incisa* sub-sp. n.

Brachymetra unca sp. n.

(Pl. 1, figs. 2, 2a, 2b, 2c)

APTEROUS FORM

Size. Length of males 6.5 mm., females 6.1 mm.; width of males 2.5 mm., females 2.8 mm. at widest place.

Color. Chocolate brown above, venter yellowish brown, dull pubescence with a varnished background. A median dark line extending throughout the length of the pronotum, metanotum and the first abdominal segment. Margins of pronotum and connexiva dark. Caudal margin of last abdominal segment of male dark, with the genital segments somewhat dark; caudal margin of last abdominal segment and genital segments of female dark. Meso- and metathoracic acetabula dark above. Tip of rostrum, eyes, antennæ, and legs dark, except the anterior coxæ, trochanter and basal half of the femora, which are about same shade as venter.

Structural Characteristics. Antennal formula of male: 1st : 2d : 3d : 4th :: 30 : 11 : 18* : 15; female : 26 : 10 : 16.5 : 14. Eyes rather

* Includes tiny basal ring segment.

small in comparison to size of body, less than one-half the length extending caudad of the posterior angle of the head. Interocular space about four-fifths the length of eye. Sides of prothorax almost parallel with the sides of mesothorax inflated. Length of pronotum on median line is to length of metanotum exposed as 6.8 : 1 (both sexes). Anterior femur as long as the pronotum on its median dorsal line; in the male this femur is fully twice as large as intermediate femur and distinctly arched, while in the female it is about one and one-half times as large as intermediate femur and quite straight; tibia slightly shorter than femur, somewhat curved on distal third, its tip slightly, if any, produced beyond base of tarsus; first tarsal segment one-half as long as the second. Intermediate femur a trifle shorter than body; tibia about one-seventh longer than the femur and over four times as long as tarsus; first tarsal segment three times as long as the second. Posterior femur about one-fifth longer than intermediate femur and almost twice as long as tibia; tibia almost four times as long as its tarsus; first tarsal segment over one and one-half times as long as the second. In the female the last abdominal segment surpasses the apex of posterior trochanter. In the male the genital segments are one-half to three-fifths the length of the abdomen, the abdomen surpassing the posterior trochanter by about one-third the length of the last segment; the last ventral abdominal segment as long as the two preceding combined in the male and as long or longer than the three preceding combined in the female. In the male the claspers are so long and curved that they overlap slightly on the dorsal side of the second genital.

Described from a series of twenty specimens labeled, "Trinidad, B. W. I., Port of Spain, Nov. 5, 1931, W. E. Broadway," and the same data "near St. Patrick Oct. 25, 1931." Holotype, allotype and paratypes in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

MACROPTEROUS FORM

Size. Length to tip of elytra, 7.3 mm.; width, 2.5 mm.

Color. Same color as in apterous form. A median dark line on pronotum, extending from anterior margin to beyond the middle. Elytra, including veins, black with apices somewhat fuscous.

Structural Characteristics. Lateral margins of pronotum back of humeral angles more depressed than in related species, depressed area at apex about equals the head in length. Anterior femur one-

fifth shorter than pronotum. Elytra exceed abdomen by over half the length of the head.

Described from a single male specimen labeled, "Trinidad, B. W. I., Port of Spain, Nov. 5, 1931, W. E. Broadway." Holomorphotype deposited in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

Brachymetra vittata sp. n.

(Pl. 1, figs. 3, 3a)

MACROPTEROUS FORM

Size. Length of male, 9.3 mm., female, 9 mm.; width of male, 3.3 mm., female, 3.3 mm.

Color. A striped species; clay-yellow with head almost reddish-brown, venter yellowish. Heavy black band bordering lateral margins of pronotum and continuing slightly inside the margin from the humeral angles to the apex, a pair of heavy black bands extending from anterior end two-thirds the way along the median line. Margins of connexiva dark. Anterior acetabulum with black spot on dorsal side, a black spot on lateral side of prothorax dorsad and caudad of this. An oblique black band running slightly ventrad along lateral side of mesothorax, with slight break which is followed by a broader band on the mesothoracic acetabulum. A solid band also originates posterior to the mesothoracic spiracle and continues unbroken to apex of metathoracic acetabulum. Two black spots are just below the spiracles of each abdominal segment of female. A black spot on vertex next to each eye continuous with median bands of pronotum, a third spot on median line about half way between these and rostrum. Eyes, antennæ and tip of rostrum, dark. Anterior femur with apex and ventral side dark, tibia and tarsus also dark. Meso- and metathoracic legs somewhat dark with apex of mesothoracic femur black preceded preapically by light brown. Elytra including veins black; caudal half of costal margin light brown.

Structural Characteristics. Antennal formula of female: 1st : 2d : 3d : 4th :: 44 : 18 : 23 : 20 (no antennæ on male specimen). Eyes quite small in comparison to size of body, less than one-half the length extending caudad of the posterior angle of the head. Interocular space three-fourths the length of the eye. Apex of pronotum blunter than in other species, margin narrowly depressed. Anterior femur not as stout as in *B. unca* but arched apically (no prothoracic or right meso- and metathoracic legs present on the male), equal in length to the pronotum on its median line; tibia almost as long

as femur and somewhat curved apically, its tip produced slightly beyond base of tarsus; first tarsal segment one-half to three-fifths as long as the second. Intermediate femur a trifle longer than body in female, and about one-fourth longer in the male; tibia slightly shorter than the femur and almost three times as long as tarsus; first tarsal segment about three times as long as second. Posterior femur barely longer than intermediate femur and two-thirds longer than the tibia; tibia over four times as long as tarsus; first tarsal segment about one-fourth longer than second. In the female the last two abdominal segments exceed tip of posterior trochanter. In the male the genital segments only one-half longer than the posterior abdominal segment, the abdomen surpassing the posterior trochanter by about the length of the last segment. The last ventral abdominal segment about one and one-fourth times as long as preceding one in the male and over one and one-half times as long as preceding one in the female. In the male the claspers do not exceed the posterior margin of the first genital and are scarcely visible between the first and second genital. Elytra exceed abdomen by over one-half the length of head.

Described from single male and female specimens labeled, "Marianie Port au Prince, Haiti, July 10, 1930, R. M. Bond." Holotype and allotype in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

APTEROUS FORM

Size. Length of females, 8.4 mm.; width, 3.3 mm.

Color. Color markings mostly as in the macropterous forms. Median bands on pronotum almost continuous to base. Wide, black band originating laterad of median bands of pronotum and extending posteriorly, bifurcating preapically at the base of the pronotum, one branch continuous with the black margin of connexivum and the other running around apex of pronotum and meeting band from other side at the median line of the tergum of the metathorax. Terga of abdominal segments mostly black.

Structural Characteristics. Same as in the macropterous forms with the exception that the apex of the pronotum is less blunt, exposing only the posterior margin of the mesothorax; lateral margins more parallel and lacking the rather acute humeral angles.

Described from four female specimens labeled, "Marianie Port au Prince, Haiti, July 10, 1930, R. M. Bond." Holomorphotype and paramorphotypes in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

Brachymetra kleopatra Kirk.

(Pl. 1, fig. 5)

Brachymetra kleopatra Kirkaldy. Bolletino dei Musei di Zoölogia Anatomia Comparata, Torino, vol. XIV, No. 350, 1899, p. 3.

Kirkaldy's original description of this species fits the single female I have on hand with the following exceptions: (1) The specimen which I have before me measures 8.2 mm. long and 3 mm. wide, while he gives measurements of 9¾ mm. long and 2.5 mm. wide. (2) "Head and pronotum very smooth and polished." I find both to be quite pubescent except for smooth spot on vertex between the eyes (apparently having been rubbed smooth).

The specimen at hand is lacking antennal segments and anterior legs. I will quote Mr. Kirkaldy's descriptions of these parts.

Color. Reddish-brown above, venter tan. Tip of meso- and metathoracic acetabula dark. Two darkened spots just below spiracle of each abdominal segment. Eyes dull wine, rostrum tip dark, and the legs dark brown. Elytra velvety brown with veins grayish brown.

Structural Characteristics. "First segment of the antennæ shorter than the second and third together, first segment rather more than twice as long as the second, second and fourth subequal, third one-third longer than the second." Eyes rather small in comparison to size of body, about one-half the length extending caudad of the posterior angle of the head. Interocular space about four-fifths the length of eye. The apex of pronotum most widely depressed and most acutely produced of all the species of the genus, being produced well beyond the apices of metathoracic acetabula. "Anterior tibia one-fourth longer than the femur, three and a quarter times longer than tarsus, second segment of the latter two-thirds longer than the first." Intermediate femur about one-tenth shorter than body; tibia slightly longer than femur and three times as long as tarsus; first tarsal segment about five times as long as second. Posterior femur equals the length of the body and one-tenth longer than intermediate femur and almost twice the length of the tibia; tibia three times as long as tarsus; first tarsal segment over twice the second. The last two abdominal segments exceed the posterior trochanter. Last ventral abdominal segment almost as long as two preceding. Elytra exceed abdomen by one-half the length of head. The single female specimen on hand is labeled, "British Guiana, S. A., near New Amsterdam, July 30, 1923, F. X. Williams."

Brachymetra lata sp. n.

(Pl. XX, figs. 4, 4a, 4b)

APTEROUS FORM

Size. Length of males, 7 mm., females, 7 mm.; width of males, 2.5 mm., and females, 2.7 mm.

Color. Reddish-brown above, venter a lighter shade of brown. Margins of pronotum dark, median line light. Margins of connexiva dark. Genital segments mostly dark, caudal half of the last abdominal tergum of male dark. Tip of metathoracic acetabula dark while that of the mesothorax is light with a brown spot borne preapically. Eyes brown mottled with dark spots, tip of rostrum, antennæ and legs dark, except anterior coxæ, trochanters and basal half of anterior side of femora.

Structural Characteristics. Antennal formula of male: 1st : 2d : 3d : 4th :: 29 : 15 : 22.5 : 16; female: 27 : 14 : 20 : 15. Eye about one and one-half times longer than wide, larger in comparison to size of body, over one-half the length, with its rear margin slightly greater than interocular space, extending caudad of the posterior angle of the head. Interocular space about three-fifths the length of eye. Head, including eyes, considerably wider than prothorax. Pronotum with apex bluntly produced, length on median line is to length of metanotum exposed as 5.6 : 1 (both sexes). Anterior femur not much stouter than intermediate femur, but somewhat arched apically, slightly longer, if any, than pronotum on its median line. Tibia shorter than femur and barely curved on its distal end, its tip produced slightly beyond base of tarsus; first tarsal segment about two-thirds as long as second. Intermediate femur about equal in length to body of male, but almost one-tenth shorter in the female; tibia equal to length of femur in male, but slightly longer in female, and five and one-half to six times as long as tarsus; first tarsal segment three times as long as second in male and three and one-half times as long in female. Posterior femur one-seventh longer than intermediate femur and over twice the length of its tibia; tibia four and one-half times longer than its tarsus; first tarsal segment about one-third longer than the second. In the female the last two abdominal segments exceed tip of posterior trochanter. In the male the genital segments are about one-fourth the length of the abdomen, the abdomen surpassing the posterior trochanter by the last segment. Last ventral abdominal segment about four-fifths as long as the two preceding combined in the male and as

long in the female. A pair of rather straight claspers barely exceed, if any, posterior margin of first genital.

Described from a series of 160 labeled, "Manacapuru, S. A., Amazonas, Brazil, Solimoes river, 6. 26, S. M. Klages." Holotype, allotype and paratypes in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

MACROPTEROUS FORM

Size. Length of males to tip of elytra, 7.4 mm., females, 7.4 mm.; width of males, 2.5 mm. and females, 2.7 mm.

Color. Same color as in apterous forms. Margin of pronotum indistinctly darkened. Elytra a rich velvety brown, paler at apices, veins a rich yellow.

Structural Characteristics. Pronotum with apex about as blunt as in apterous forms. Anterior femur slightly shorter than pronotum on its median line. Elytra exceed abdomen by about half the length of head or less.

Described from a series of 114 with same data as for apterous forms. Holomorphotype, allomorphotype and paramorphotypes in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

Brachymetra albinerva (A. & S.)

(Pl. XX, figs. 1, 1a, 1b, 1c.)

Brachymetra albinerva (Amyot et Serville). Hist. Nat. Ins. Hem., 1843, p. 412.

APTEROUS FORM

Size. Length of males, 5.4-6.8 mm., females, 5.5-6.9 mm.; width of males, 2.3-2.7 mm., and females, 2.5-3.1 mm.

Color. Dull chocolate brown above, venter lighter. Margins of pronotum and connexiva dark. Genital segments dark. Mesothoracic and metathoracic acetabula darkened above. Eyes and tip of rostrum dark. Antennæ and legs same shade as the body or a little darker except the anterior femora, which are lighter on the dorsal basal two-thirds.

Structural Characteristics. Antennal formula of male: 1st : 2d : 3d : 4th :: 21 : 11 : 15 : 12; female: 20 : 11 : 15 : 11.5; in the larger specimens it measures as follows, male: 25 : 14 : 18 : 14; female: 23 : 14 : 16 : 15. Eye with its rear margin about equal to interocular space, one-half the length of eye extending caudad of the posterior angle of the head. Interocular space two-thirds the length of eye. Head, including eyes, only slightly wider than prothorax. Length

of pronotum on median line is to length of metanotum exposed as 6.5 : 1 (both sexes). Anterior femur arched and at least one and one-half times larger than intermediate femur, about one-fifth shorter than pronotum on its median line; tibia slightly shorter than femur, curved on distal third, its tip barely produced beyond base of tarsus; first tarsal joint three-fourths as long as second. Intermediate femur one-ninth shorter than body; tibia about one-tenth longer than femur and over three and one-half times as long as tarsus; first tarsal segment slightly more than three times as long as the second. Posterior femur about one-tenth longer than intermediate femur and about twice as long as its tibia. Tibia over three times as long as its tarsus. First tarsal segment about one and one-half times as long as the second. In the female the last two abdominal segments exceed the posterior trochanter. In the male the genital capsule usually only slightly longer than the posterior abdominal segment, while in specimens with it greatly protruding it may be one-third the length of abdomen, the abdomen surpassing the posterior trochanter by about the length of the last segment. The last ventral abdominal segment one and one-half times as long as preceding in the male and twice as long as preceding in the female. In the male the claspers extend beyond first genital and are strongly curved upward and laterad of second genital.

Specimens are at hand from the following localities: Banos, Mera, Tena, and Huigra, Ecuador, and Sao Paulo, Brazil, South America; Trinidad, B. W. I.; and Fort Clayton and Barro Colo Island, Canal Zone.

MACROPTEROUS FORM

Size. Length of males, 6 mm., females, 6.1 mm.; width of males, 2.3 mm., and females, 2.4 mm.

Color. Same color as in apterous forms. Elytra of the same shade of brown as the body or darker, veins yellowish.

Structural Characteristics. Anterior femur definitely shorter than pronotum on its median line. Elytra exceed abdomen by at least one-half the length of head.

Specimens on hand from the following localities: Mera and Huigra, Ecuador, South America: and Fort Clayton and Barro Colo Island, Canal Zone.

Brachymetra albinerva incisa subsp. n.

APTEROUS FORM

Size. Length of males, 5.4 mm., females, 5.6 mm.; width of males, 2.4 mm., and females, 2.5 mm.

Color. A subspecies which is yellowish brown above, venter paler, almost yellowish. Lateral margins of pronotum and connexiva distinctly darkened by a narrow band, as well as the posterior margins of abdominal terga. Meso- and metathoracic acetabula darkened on apical margins. Eyes and tip of rostrum dark. Antennæ and legs about same shade as the body or a little darker, except the anterior femora, which are lighter on the dorsal basal two-thirds, apices of femora and tibia darkened.

Structural Characteristics. Structurally the same as *B. albinerva*, but the following morphological characteristics, along with the color, have made me feel justified in calling this series a subspecies. Antennal formula of male: 1st : 2d : 3d : 4th :: 18.5 : 10.5 : 14.5 : 11.5; female: 18 : 19 : 14 : 11. When the first antennal segment of *B. albinerva incisa* is turned back it about attains rear lateral margin of eye, while in *B. albinerva* it plainly surpasses rear lateral margin of eye. The first abdominal tergite of *B. albinerva incisa* is deeply incised behind, while in *B. albinerva* it is shallowly incised.

MACROPTEROUS FORM

Size. Length of males, 6 mm., females, 6.4 mm.; width of males, 2.3 mm., and females, 2.5 mm.

Color. Same color as in apterous forms. Elytra of the same shade of brown as the body or darker, veins yellowish.

Structural Characteristics. Anterior femur about one-fourth shorter than pronotum on its median line. Elytra exceed abdomen by at least one-half the length of head.

Both forms described from a series of 37 specimens labeled, "Santa Cruz, Bolivia, S. A., J. Steinbach." Holotype, holomorphotype allotype, allomorphotype, paratypes, and paramorphotypes in the Francis Huntington Snow Entomological Museum, University of Kansas, Lawrence, Kansas.

PLATE XX

FIGS. 1, 1a, 1b, 1c. *Brachymetra albinerva* (A. & S.).

Fig. 1. Head and pronotum of macropterous form.

Fig. 1a. Apical end of abdomen showing genital segments and claspers, ventral view.

Fig. 1b. Lateral view of fig. 1a.

Fig. 1c. Clasper.

FIGS. 2, 2a, 2b, 2c. *Brachymetra unca* sp. n.

Fig. 2. Head and pronotum of macropterous form.

Fig. 2a. Apical end of abdomen showing genital segments and claspers, ventral view.

Fig. 2b. Lateral view of fig. 2a.

Fig. 2c. Clasper.

FIGS. 3, 3a. *Brachymetra vittata* sp. n.

Fig. 3. Head and pronotum of macropterous form.

Fig. 3a. Apical end of abdomen showing genital segments and claspers, ventral view.

FIGS. 4, 4a, 4b. *Brachymetra lata* sp. n.

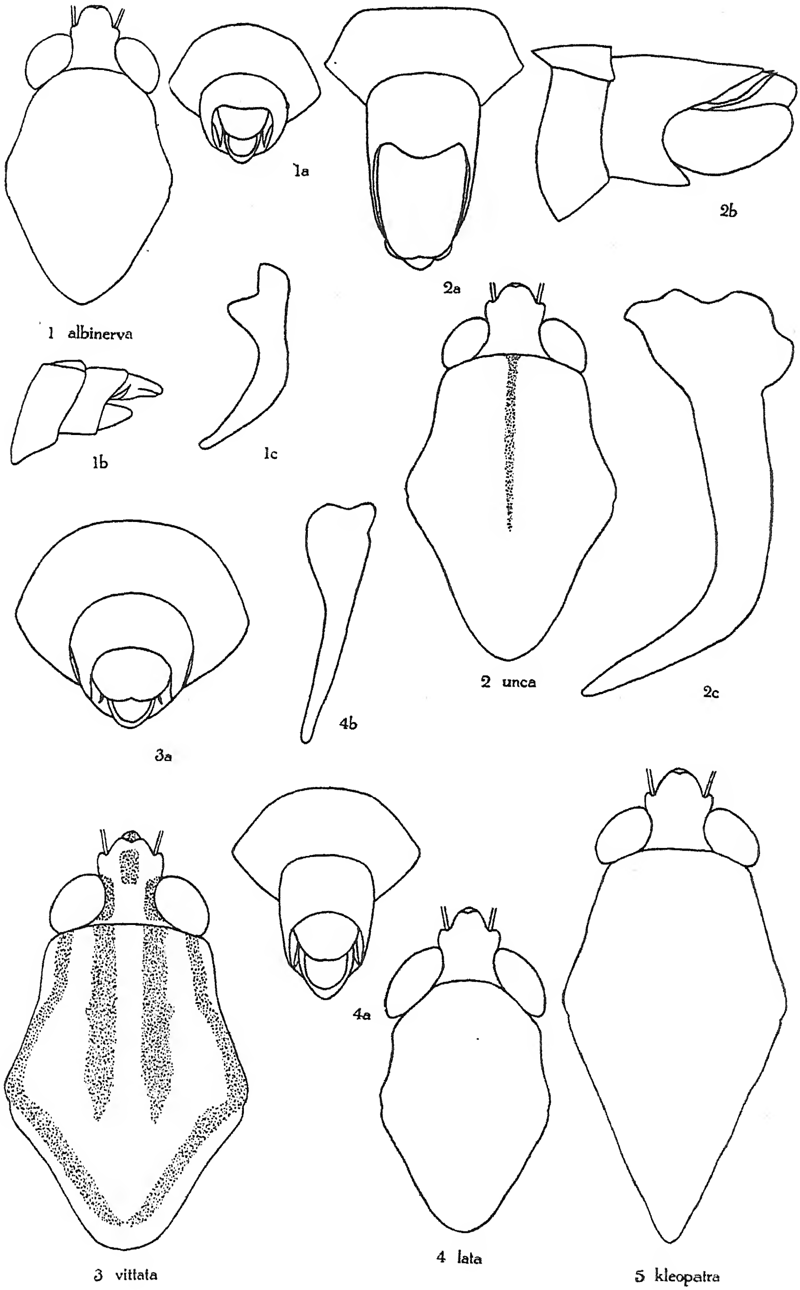
Fig. 4. Head and pronotum of macropterous form.

Fig. 4a. Apical end of abdomen showing genital segments and claspers, ventral view.

Fig. 4b. Clasper.

FIG. 5. *Brachymetra kleopatra* Kirk. Head and pronotum of macropterous form.

PLATE XX


1a
2a
2b
1 albinerva
1b
1c
2 unca
2c
4b
3a
4a
3 vittata
4 lata
5 kleopatra

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The Genus Chlorotettix in America North of Mexico

(Homoptera—Cicadellidæ)

WILLIAM F. BROWN, Lawrence, Kansas.*

TABLE OF CONTENTS

Abstract: New distributional records are given for twenty-one of the previously know species of the genus, in a number of cases greatly extending their known range. Twelve species are described as new to science and a key to all the known species is provided.

Most species of the genus Chlorotettix are found in North America, north of Mexico. The genus was founded in 1892 by Van Duzee. New species have been added by Van Duzee, Osborn, Ball, Baker, Crumb, Sanders, De Long and the author until there are at present forty-six species and one variety north of Mexico. This paper describes twelve new species and the male of *C. latifrons*.

Most species of the genus have a uniform green or yellow color; a few are tinged with fuscous; a few have dark spots or bands on the head, pronotum or scutellum.

The vertex is usually broad, either rounded or distinctly angled and rounding with the front. The ocelli are on the margin of the

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vertex and near the eyes. The elytra have three antiapical cells, are longer than the abdomen, subhyaline, with a distinct appendix, the nervures usually indistinct. The species vary in length from 3.5 to 8 mm.

The members of this group usually feed on grasses; thus they are plentiful as well as of some economic importance.

Some species of the genus have a wide range, while others are found within narrow limits. In the following notes are additional records of the distribution of a number of species.

C. viridius has previously been reported from the following states: Connecticut, New York, New Jersey, Maryland, Tennessee, Virginia, North Carolina, South Carolina, Florida, Alabama, Mississippi, Louisiana, Texas, Arkansas, Kansas, Ohio and Michigan. In the Snow collection are also specimens from Georgia. This species thus seems to be distributed well over the eastern half of the United States.

C. vividus has been reported for Tennessee, South Carolina, Ohio and Kansas. Specimens are at hand from these additional states: Arizona, Missouri, Arkansas, Mississippi, Alabama, Georgia, Florida, and North Carolina.

C. tergatus has formerly been reported for New York, Maine, Connecticut, Michigan, Wisconsin, Washington, Iowa, Illinois, Ohio, New Jersey, Pennsylvania, Virginia, Tennessee, South Carolina and Florida. Specimens are at hand from Minnesota. Specimens formerly called *C. tergatus* examined from the southern states proved to be either *C. fumidus* or *C. divergens*. It is doubtful, therefore, whether the records of *C. tergatus* from such states as Virginia, Tennessee, South Carolina and Florida are correct.

C. dentatus was described by Sanders and De Long from specimens taken near Washington, D. C. In the Snow Entomological Collection is a specimen collected at Atherton, Missouri.

C. lusorius has previously been reported from Iowa, Ohio, New York, New Jersey, Pennsylvania, New Hampshire, Connecticut, Virginia, Wisconsin, Colorado and Utah. To these may be added Minnesota, Illinois and Arizona.

C. limosus was described from specimens collected in Pennsylvania. Before us are also specimens from Kansas, Missouri, Mississippi, Alabama and New York.

C. balli has been reported from Iowa, Ohio, Tennessee, South Carolina, Virginia, New York and Connecticut. Our specimens have been taken in Kansas and Vineland, Ontario, also.

C. galbanatus has previously been taken in Iowa, Ohio, Kansas, Montana, Wisconsin, North Dakota, Connecticut, Maine, New York, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Tennessee, Florida and Louisiana. The following states are new: Missouri, Arkansas, Texas, Mississippi, Alabama, Georgia, and New Jersey.

C. necopinus is a southern species described from specimens collected in Mississippi. It has been collected previously from Kansas, Tennessee, North Carolina, South Carolina and Florida. It has also been taken in Arkansas, Texas, Louisiana and Alabama.

C. spatulatus has a wide distribution, having been reported from Iowa, Kansas, Nebraska, Colorado, Ohio, Wisconsin, Connecticut, Virginia, South Carolina, Tennessee and Florida. New localities are Missouri, New Mexico, Minnesota, Texas, Mississippi, Alabama and Georgia.

C. rugicollis has been collected in Florida, Texas, Tennessee, South Carolina and New Jersey. New states to add to this list are: Kansas, Arkansas and Alabama.

C. suturalis type specimens are from Tennessee. Our collection shows specimens from Mississippi, Alabama, Georgia and South Carolina.

C. minor was taken in Texas. A specimen is at hand from Kansas. This species is evidently very uncommon.

C. nudatus has formerly been reported from Iowa, Tennessee and Connecticut. Our specimens are all from Douglas county, Kansas.

C. latifrons was described from specimens taken in Virginia, later found in Mississippi. We have specimens also from Alabama.

C. similis was originally described from specimens collected in Oregon. We also have specimens from Washington and California.

C. fumidus has previously been reported as taken from Pennsylvania and Tennessee. The writer adds to the list: Missouri, Mississippi, Alabama and Georgia.

C. divergens has been reported for Virginia only, but we have specimens collected in Alabama, Mississippi, and Arkansas.

C. productus was described from Virginia, later taken in Florida. The following states are added to the list: Louisiana, Mississippi, Georgia and Texas.

C. unicolor is common in many localities and thus has been reported from many of the northern states and Canada. Specimens had formerly been reported for Maine, Connecticut, New Hampshire, New York, Wisconsin, Ohio, Iowa, Nebraska, Colorado, Cali-

fornia, Oregon, Washington, British Columbia, and Ontario, Canada. Specimens are at hand from the following new localities: Michigan, Minnesota, Montana, Utah and Arizona.

C. tunicatus is widespread over the southeastern quarter of the United States. Specimens have been reported for Kansas, Missouri, Arkansas, Texas, Louisiana, Tennessee, Florida, South Carolina, North Carolina and Virginia. Alabama and Mississippi are here added to the list.

In making an artificial key to the species, the most outstanding characteristics used are: shape of the vertex, male valve and plates, and the last ventral segment of the female. Size and color have been used in a more general way.

Due to the fact that many species are very similar in appearance, it is sometimes difficult to distinguish between specimens by using only the above characteristics. Drawings of the male internal genitalia of the new species are included, in order to assist in determining specimens. These structures furnish definite and clear-cut characters for the determination of the species.

In the preparation of this paper the writer has used, for examination and dissection, specimens from the Snow Entomological Collection.

This paper has been worked out and written under the supervision of Dr. Paul B. Lawson, of the Department of Entomology of the University of Kansas. Dr. Dwight M. De Long and Mr. S. E. Crumb kindly helped with the comparison of some specimens and the loan of material.

KEY TO SPECIES OF CHLOROTETTIX*

1. Vertex with anterior margin rounded, length at middle equaling or slightly exceeding next the eye 2
   Vertex with anterior margin distinctly but bluntly angulate, distinctly longer at middle than next the eye 24
2. Size small, not larger than 5 mm 3
   Size larger, length more than 5.5 mm 5
3. Posterior margin of female last ventral segment produced at middle, but without median notch; male valve very short, plates gradually narrowed to produce fingerlike apices .... *minor*.
   Posterior margin of female last ventral segment produced at middle, but with a median notch; male valve longer, plates without fingerlike apices 4
4. Notch in female last ventral segment very short; plates with lateral margins almost straight, gradually narrowed to rather broad, blunt apices .... *productus*.
   Notch in female last ventral segment reaching nearly to base; plates gradually and evenly narrowed to sharp-pointed tips .... *minimus*.
5. Vertex not longer at middle than next the eye 6
   Vertex at least slightly longer at middle than next the eye 7

* This key has been made by using D. M. De Long's key from his "A synopsis of the Genus Chlorotettix" as a pattern.

6. Lateral lobes of female last ventral segment distinctly angulate; and male plates narrow and at most but slightly upturned apically....................... *latus.*
Lateral lobes of female last ventral segment broadly rounded, and male plates broad with strongly upturned apices....................................... *dozieri.*
7. General color dark, brownish or sordid green.................................. 8
General color light, greenish or yellow... 12
8. Size large, 8 mm.; pronotum, scutellum and dorsal portion of elytra fuscus...*fuscus.*
Size smaller, near 7 mm.. 9
9. Sordid green without bands or stripes.. 10
Vertex pale with broad brown band between eyes, elytra dark with pale nervures, giving it a striped appearance...................................... *necopinus.*
10. Size large, 7.5 mm. or more, male plates short........................... *fallax.*
Size small, less than 7.5 mm., often appearing almost black in color; male plates of medium length... 11
11. Vertex more subangulate, lighter color................................... *tergatus.*
Vertex more rounded, a distinctly blacker color............ *tergatus var. melanotus.*
12. Vertex or elytra with red or dark markings.................................... 13
Vertex and elytra greenish or yellowish.. 14
13. Margin of vertex with more or less distinct broad red or orange band between eyes, elytra unmarked .... *rugicollis.*
Margin of vertex without red band but with two dark spots, elytra yellowish green with a more or less distinct dull, three-lobed fuscus stripe along the suture. *surturalis.*
14. Head subangulate, body quite narrow, a cross nervure between the two inner veins of clavus .... *occidentalis.*
Head rounded, body usually broad, inner veins of clavus without a cross nervure.... 15
15. Female last ventral segment notched, bearing spatulate process from its apex; male valve broad and short, plates long, gradually tapering......................... 16
Female last ventral segment notched, but without spatulate process; male valve and plates variable 17
16. Spatulate process not cleft at apex; styles not extending past plates...... *spatulatus.*
Spatulate process cleft at apex; styles extending past plates and visible from below .... *limosus.*
17. Female segment with sides of notch each bearing a lateral median acute tooth; male plates short .... *viridius.*
Female segment with sides of notch without acute tooth; male plates longer........ 18
18. Size large, 6.5 mm. or more.. 19
Size small, 6.5 mm. or less... 21
19. Color greenish yellow, female last ventral segment with median notch reaching to base; notch and posterior margin bordered with dark brown; male valve very short, plates broad and short, about three times length of valve........ *latifrons.*
Color uniform pale green, female last ventral segment with median notch reaching not more than one-third distance to base...................................... 20
20. Female last ventral segment long, with a broad, shallow notch, narrowed toward apex, posterior margin of lobes sinuate; male plates narrowed at half their length, then produced .... *unicolor.*
Female last ventral segment longer and narrower, narrow median notch reaches one-third distance to base, sides convexly rounded and often overlap along median line, posterior margin of lobes rounded; male plates broader and longer than in *unicolor* .... *similis.*
21. Head broader, 1.75 mm., more rounded, body more robust...................... 22
Head narrower, 1.5 mm., more angulate, body narrower........................... 23
22. Color pale yellow, some almost colorless, female last ventral segment with lateral angles rounded; male valve with apex a right angle.................. *pallidus.*
Color greenish yellow, female last ventral segment with lateral angles broadly obtuse; male valve with apex broadly obtuse.................................. *rubidus.*
23. Eyes dark; color dark yellow; posterior margin of female last ventral segment with deep notch with sides strongly convex.............................. *convexus.*
Eyes red; color pale yellow; male valve broad at base, rounded at apex; plates narrower than valve, about three times the length; pygofer one-half longer than plates .... *durus.*

24. Vertex usually with distinct transverse band across middle between eyes............ 25
Vertex without definite markings in the form of either spots or bands.............. 26
25. Size large, 7.5 mm., distinctly reddish brown in color.....................*lusorius.*
Size smaller, less than 7 mm., color yellowish green......................*scutellatus.*
26. General color brownish or sordid green.. 27
General color light, pale green or yellowish.................................. 31
27. Vertex subangulate to rounded...*rotundus.*
Vertex angulate 28
28. Median notch in female last ventral segment U-shaped........................ 29
Median notch in female last ventral segment V-shaped.......................... 30
29. Sides of median notch in female last ventral segment toothed.............*sordidus.*
Sides of median notch in female last ventral segment not toothed........*divergens.*
30. Lateral angles of last ventral segment of female acute and prominent; sides of notch not tinged with brown...*iridescens.*
Lateral angles of last ventral segment of female obtuse; sides of notch tinged with brown ....*fumidus.*
31. Small, not more than 6.5 mm.. 32
Larger, 6.5 mm. or more.. 41
32. Vertex distinctly angled, almost twice as long at middle as next the eye, sometimes conical 33
Vertex more bluntly angled, not more than one-half longer at middle than next the eye 34
33. At least 5.5 mm. in length, male valve sinuate, apex notched, apices of plates not produced in long fingerlike processes...............................*vividus.*
Length 4.5 mm., male valve obtusely rounded, apices of plates produced in long fingerlike processes ....*delta.*
34. Small, not exceeding 5 mm. in length.. 35
Large, 6 to 6.5 mm. in length.. 36
35. Female last ventral segment with a rather broad V-shaped notch, lateral angles slightly produced, male plates broad.................................*borealis.*
Female last ventral segment with a very narrow notch, lateral angles strongly produced; male plates narrow and parallel on apical half.................*excultus.*
36. Lateral lobes of female last ventral segment broad and more or less rounded........ 37
Lateral lobes of female last ventral segment angled or angularly rounded........... 40
37. Notch in female last ventral segment extending more than half distance to base..... 38
Notch in female last ventral segment extending half or less than half distance to base, 39
38. Eyes red; posterior margin of last ventral segment concavely rounded.....*capensis.*
Eyes dark; posterior margin of last ventral segment convexly rounded...*galbanatus.*
39. Dark spot on median line of base of last ventral segment...............*maculosus.*
Without dark spot on last ventral segment............................*angustus.*
40. Vertex about one-third longer at middle than next the eyes; female segment with the sides of notch convexly rounded..................................*vacunus.*
Vertex longer, one-half longer at middle than next the eyes; sides of female notch concavely rounded ....*distinctus.*
41. Female segment notched, bearing a spatulate process at its apex.................. 42
Female segment usually notched but without spatulate process.................... 44
42. Last ventral segment of female with spatulate process twice as long as wide....*balli.*
Last ventral segment of female with spatulate process about equal in length and width 43
43. Lateral angles of last ventral segment acute and prominent, sides of notch concave; male plates long and slender apically..............................*attenuatus.*
Lateral angles of last ventral segment obtuse and not prominent, sides of notch sinuate ....*sinuosus.*
44. Last ventral segment of female with side margins short, rounding to posterior margin which is notched giving the appearance from the ventral side of four teeth. *dentatus.*
Last ventral segment of female with side margins longer than at center of median notch 45
45. Length, 7 mm...†*tunicatus.*

† *C. tunicatus* has variation in shape of vertex from subangulate to rounded.

Length, more than 7 mm. 46

46. Female segment slightly emarginate with a brown spot at center; male valve notch at middle . . . . *stolatus.*

Female segment black margined, with notch at center, broadly, shallowly emarginate either side; male valve rounded, without notch. . . . . *nudatus.*

Chlorotettix angustus sp. n.

(Pl. XXI, fig. 7; Pl. XXII, figs. 5, 5a; Pl. XXIII, figs. 8, a-c)

Resembling *galbanatus,* but with notch in last ventral segment of female excavated only one-half distance to base instead of nearly to base; male genitalia distinct. Length, 6 to 6.5 mm. Vertex obtusely angled, one-half longer at middle than next the eye.

Color. Greenish-yellow. Eyes dark. Elytra subhyaline. Ventral side greenish-yellow. Tarsal claws black.

Genitalia. Last ventral segment of female twice as long as preceding segment, with lateral angles obtusely angled and prominent; posterior margin with a median, narrow, V-shaped notch reaching one-half distance to base; ovipositor slightly exceeding pygofer. Male valve broad at base and obtusely angled on posterior margin, about one and one-half times as long as preceding segment; plates long, slightly less than three times length of valve, broad at base, gradually becoming broader for one-third distance from base then gradually narrowing to obtuse apex; about same length as pygofer with inner margins meeting in a furrow.

Holotype. Female, Batesburg, S. C., August 24, 1930, L. D. Tuthill.

Allotype. Male, same data.

Types deposited in Snow Entomological Collection.

Chlorotettix attenuatus sp. n.

(Pl. XXI, fig. 12; Pl. XXII, figs. 6, 6a; Pl. XXIII, figs. 5, a-c)

Resembling *balli,* but with shorter spatulate process in female and with male plates more narrowed in apical half. Length, 6.75 to 7 mm. Vertex one-half longer at middle than against the eye, subangulate.

Color. Yellowish-green. Eyes dark. Elytra subhyaline, somewhat smoky apically. Underside uniformly yellowish-green except for brownish tarsal claws.

Genitalia. Last ventral segment of female with lateral angles prominent and distinctly angulate; posterior margin smoothly excavated to about one-half the length of the segment and bearing a short spatulate process which is about as wide as long; ovipositor slightly exceeding pygofer. Male valve large, subangulate; plates

broad basally, then slightly narrowed to long and acute spine which about equals the pygofer; pygofer, viewed laterally, excavated on posterior margin between an upper and a larger lower lobe.

Holotype. Female, Atherton, Mo., July 2, 1922, C. F. Adams.

Allotype. Male, same data.

Paratype. Male, Atherton, Mo., June 18, 1922, C. F. Adams.

Types deposited in Snow Entomological Collection.

Chlorotettix convexus sp. n.

(Pl. XXI, fig. 4; Pl. XXII, fig. 11)

Resembling *vacunus*, but with vertex more rounded and notched in last ventral segment, broader at apex. Length, 6 to 6.25 mm. Vertex rounded and one-third longer at middle than next the eye.

Color. Greenish-yellow. Eyes dark. Elytra subhyaline tinged with yellow. Ventral side yellow. Tarsal claws brown.

Genitalia. Last ventral segment of female with lateral angles large, distinctly but obtusely angled; posterior margin broadly excavated three-fourths distance to base, sides of notch strongly convex and apex tinged with brown; ovipositor slightly shorter than pygofer.

Holotype. Female, Gulfport, Miss., August 1, 1921, C. J. Drake.

Paratype. Female, Woodville, Miss., July 25, 1921, C. J. Drake.

Holotype deposited in Snow Entomological Collection; paratype in Doctor Drake's Collection.

Chlorotettix durus sp. n.

(Pl. XXI, 5; Pl. XXII, fig. 12; Pl. XXIII, figs. 3, a-c)

Resembling *rugicollis*, but with distinct genitalia and slightly smaller. Length, 6 mm. Vertex rounded, one-third longer at middle than next the eye.

Color. Greenish-yellow. Eyes red. Elytra subhyaline. Ventral side yellow. Tarsal claws brown.

Genitalia. Male valve one-third longer than preceding segment, broad at base, rounded at apex; plates narrower at base than valve, gradually becoming wider to middle then slowly narrowing to a very obtuse or nearly truncate apex, nearly three times as long as valve; pygofer exceeding plates by one-half length of latter.

Holotype. Male, Ft. Myers, Fla., August 14, 1930, J. Nottingham.

Type deposited in Snow Entomological Collection.

Chlorotettix fuscus sp. n.

(Pl. XXI, fig. 6; Pl. XXII, fig. 13)

Resembling *necopinus*, but without dark transverse band between eyes. Length, 8 mm. Vertex one-third longer at the middle than next the eye, obtusely rounded.

Color. Pronotum, scutellum and dorsal portion of elytra fuscous; vertex, lateral margins of pronotum and of elytra lighter. Eyes dark. Dorsal and lateral sclerites of abdomen mostly black. Ventral side yellow. Tarsal claws brown.

Genitalia. Last ventral segment of female with lateral angles obtuse; posterior margin slightly concave to a median, V-shaped notch reaching two-thirds distance to base; ovipositor slightly exceeding pygofer.

Holotype. Female, Prattsville, Ala., July 21, 1930, R. H. Beamer.

Paratypes. One female, Prattsville, Ala., July 21, 1930, R. H. Beamer; 2 females, Dennis, Miss., July 6, 1921, C. J. Drake.

Two paratypes deposited in Doctor Drake's Collection; other types deposited in Snow Entomological Collection.

Chlorotettix latifrons (Sanders and De Long)

(Pl. XXI, fig. 14; Pl. XXII, fig. 2; Pl. XXIII, figs. 7, a-c)

The male is here described for the first time. Resembling *unicolor* in size and form, but greenish-yellow in color. Length to tip of pygofer 6 mm.* Vertex broadly rounded, about the same length at middle as next the eye.

Color. Greenish-yellow. Eyes dark. Elytra subhyaline. Ventral side yellow. Tarsal claws brown.

Genitalia. Male valve slightly more than one-half the length of preceding segment, broad at base, posterior margin very broadly angled; plates broad at base and short, broadening slightly at first, then narrowing slowly for first half, then rapidly to an obtuse or nearly truncate apex which does not quite reach end of pygofer; margin fringed with spines; end of pygofer incurved.

Allotype. Male, Okolona, Miss., June 29, 1921, C. J. Drake.

Allotype deposited in Snow Entomological Collection.

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* Apex of wings broken off.

Chlorotettix latus sp. n.

(Pl. XXI, fig. 9; Pl. XXII, figs. 9, 9a; Pl. XXIII, figs. 2, a-c)

With a very broad and parallel-margined head, resembling *dozieri*, but with lateral lobes of female last ventral segment more pointed, and the male plates narrower and not upturned at apex. Length, 5.75 to 6 mm.

Head distinctly wider than pronotum. Vertex very broadly rounded and about the same length at middle as next the eye. Front broad and short.

Color. Greenish-yellow. Eyes reddish-brown. Elytra, subhyaline, tinged with green. Ventral side greenish-yellow. Tarsal claws dark brown.

Genitalia. Last ventral segment of female with lateral angles strongly produced and distinctly angulate; posterior margin with a deep, V-shaped notch two-thirds distance to base; ovipositor slightly longer than pygofer. Male valve short, obtusely angled; plates broad at base, narrowing to blunt, slightly diverging apices which are a little longer than pygofer.

Holotype. Female, Hilliard, Fla., August 19, 1930, L. D. Tuthill.

Allotype. Male, Hilliard, Fla., August 31, 1930, Paul W. Oman.

Paratypes. Forty-two females and 42 males, all taken at Hilliard, Fla., August 19 and 31, 1930, by L. D. Tuthill, Paul W. Oman, R. H. Beamer, J. Nottingham.

Types deposited in Snow Entomological Collection.

Chlorotettix maculosus sp. n.

(Pl. XXI, fig. 8; Pl. XXII, fig. 4)

Resembling *balli*, but smaller and without spatulate process. Length, 6 mm. Vertex subangulate, one-third longer at middle than next the eye.

Color. Greenish-yellow. Eyes dark, tinged with red. Elytra subhyaline. Ventral side yellow. Tarsal claws light brown.

Genitalia. Last ventral segment nearly three times as long as preceding segment with lateral lobes broad and with lateral angles widely obtuse; posterior margin with a rather narrow median V-shaped notch reaching one-half the distance to base which has a faint brownish spot on median line; ovipositor slightly exceeding pygofer.

Holotype. Female, Polk county, Ark., August 21, 1928, R. H. Beamer.

Paratype. Female, Natchitoches County, La., August 16, 1928, A. M. James.

Types deposited in Snow Entomological Collection.

Chlorotettix pallidus sp. n.

(Pl. XXI, fig. 13; Pl. XXII, figs. 1, 1a; Pl. XXIII, figs. 4, a-c)

Resembling *spatulatus* in form and size but paler, without the spatulate process. Length, 5.75 to 6.5 mm. Vertex rounded and slightly longer at the middle than next the eye.

Color. Pale yellow. Eyes light to dark, some tinged with red. Elytra subhyaline. Ventral side light yellow. Tarsal claws brown.

Genitalia. Last ventral female segment with lateral angles prominent and bluntly angled; posterior margin with a broad, deep, V-shaped excavation reaching almost three-fourths the distance to base, excavation rounding at the apex; ovipositor about the same length as narrow pygofer. Male valve longer than preceding segment, apex nearly a right angle; plates broad at base, roundingly narrowing to a very obtuse, nearly truncate apex which exceeds pygofer, margin fringed with spines. Pygofer with apex blunt, with a pair of large, straight spines directed downward and backward from the ventral posterior margin.

Holotype. Female, Cameron Co., Texas, August 3, 1928, L. D. Beamer.

Allotype. Male, Cameron Co., Texas, August 3, 1928, R. H. Beamer.

Paratypes. Fifty females and 17 males, Cameron Co., Tex., August 3, 1928, by R. H. Beamer, L. D. Beamer, Jack Beamer, A. M. James, J. G. Shaw; 9 females and 7 males, Hidalgo Co., Tex., July 28, 1928, by R. H. Beamer, A. M. James; 1 female, Hidalgo Co., Tex., July 31, 1928, by R. H. Beamer; 1 female, Hidalgo Co., Tex., August 2, 1928, by R. H. Beamer; 2 females and 1 male, Brooks Co., Tex., July 25, 1928, by A. M. James; 1 female, Brazoria Co., Tex., August 10, 1928, by R. H. Beamer; 2 females and 2 males, Brownsville, Texas, June, F. H. Snow.

Types deposited in Snow Entomological Collection.

17—3482

Chlorotettix rotundus sp. n.

(Pl. XXI, fig. 10; Pl. XXII, fig. 3; Pl. XXIII, figs. 1, a-c)

Resembling *tunicatus,* but with vertex narrower, slightly browner in color, and with distinct internal male genitalia. Length, 6.5 mm. Vertex one-half longer at middle than next the eye, subangulate.

Color. Brownish-yellow. Eyes dark. Elytra subhyaline. Ventral side yellow. Tarsal claws brown.

Genitalia. Male valve slightly longer than preceding segment, broad at base, posterior margin rounded at apex; plates broad at base, gradually narrowing to a very obtuse or truncate apex, margin fringed with spines below and fine hairs above, slightly exceeding pygofer. Plates of *rotundus* similar to those of *tunicatus,* except that in *tunicatus* plates are convex below, while in *rotundus* plates are slightly concave along line where two plates meet; apices more acute in *rotundus.* Processes on end of œdagus in *rotundus* project straight from œdagus, while in *tunicatus* they project diagonally. Styles vary widely in shape.

Holotype. Male, Polk county, Ark., July 21, 1928, L. D. Beamer.

Paratypes. One male, Polk county, Ark., August 21, 1928, R. H. Beamer; 3 males, Tuskegee, Ala., July 22, 1930, L. D. Tuthill; 2 males, Shuqualak, Miss., July 16, 1930, R. H. Beamer; 1 male, Walnut, N. C., August 20, 1930, Paul W. Oman; 1 male, Scott county, Ark., August 23, 1928, R. H. Beamer; 1 male, Prattsburg, Ga., July 25, 1930, R. H. Beamer.

Types deposited in Snow Entomological Collection.

Chlorotettix rubidus sp. n.

(Pl. XXI, fig. 1; Pl. XXII, figs. 8, 8a; Pl. XXIII, figs. 6, a-c)

Resembling *capensis,* but with a less pointed vertex and lobes of ventral segment more rounded. Length, 6 to 6.5 mm. Vertex rounded, slightly longer at the middle than next the eye.

Color. Greenish-yellow. Eyes dark red. Elytra subhyaline. Ventral side greenish-yellow. Tarsal claws reddish-brown.

Genitalia. Last ventral segment of female with lateral angles broadly obtuse; posterior margin with broad median V-shaped notch, which is tinged reddish brown at apex and reaches a little more than two-thirds the distance to base; ovipositor slightly exceeding pygofer. Male valve nearly twice as long as preceding segment, very broad at base and obtusely angled; plates, three times as long as valve, broad at base, gradually becoming broader for

one-fifth distance from base, then gradually narrowing to very obtuse or truncate apex, margin fringed with hairs; pygofer slightly exceeding plates.

Holotype. Female, Plant City, Fla., August 15, 1930, J. O. Nottingham.

Allotype. Male, Hilliard, Fla., August 19, 1930, R. H. Beamer.

Paratypes. Two females, Sanford, Fla., Sept. 19, 1929, C. O. Bare; 1 female, Yankeetown, Fla., July 31, 1930, Paul W. Oman; 1 female, Natchitoches county, La., August 16, 1930, A. M. James; 1 female, Orange county, Tex., August 14, 1928, R. H. Beamer; 1 male, Plant City, Fla., June 5, 1926, C. O. Bare; 1 female, Cocoanut Grove, Fla., August 9, 1930, Paul W. Oman; 1 male, Woodville, Miss., July 25, 1921, C. J. Drake; 1 male, Homestead, Fla., August 9, 1930, J. Nottingham.

Types deposited in Snow Entomological Collection.

Chlorotettix sinuosus sp. n.

(Pl. XXI, fig. 2; Pl. XXII, fig. 10)

Resembling *balli,* but with a shorter spatulate process in female and last ventral segment not so deeply notched. Length, 6.5 to 7 mm. Vertex one-third longer at the middle than next the eye, subangulate.

Color. Greenish-yellow. Eyes dark. Elytra subhyaline. Ventral side yellow. Tarsal claws brown.

Genitalia. Last ventral segment with lateral angles roundingly angled; posterior margin sinuated, with broad, shallow, median notch reaching one-third distance to base of segment, at apex of which is a short, emarginate, spatulate process which is about as broad as long; ovipositor slightly exceeds pygofer.

Holotype. Female, Columbus, Miss., July 24, 1921, C. J. Drake.

Paratype. Female, Columbus, Miss., July 24, 1921, C. J. Drake.

Holotype deposited in Snow Entomological Collection; paratype in Doctor Drake's Collection.

Chlorotettix sordidus sp. n.

(Pl. XXI, fig. 3; Pl. XXII, fig. 7)

Resembling *tergatus*, but smaller and with vertex more angulate. Length, 7 mm. Vertex distinctly angulate, one-half longer at middle than next the eye.

Color. Sordid greenish-yellow. Eyes dark. Elytra subhyaline with a smoky, brownish tinge. Ventral side yellowish. Tarsal claws brownish.

Genitalia. Last ventral female segment very long with lateral angles much produced and distinctly angulate; posterior margin with a broad, V-shaped excavation reaching seven-eighths the distance to base, its edges tinged with brown; ovipositor longer than pygofer.

Holotype. Female, Caddo county, La., August 19, 1928, L. D. Beamer.

Paratypes. Two females, Port Gibson, July 20, 1921; 2 females, Port Gibson, July 21; 5 females, Meridian, August 14, 1921; 1 female, Yazoo City, July 6, 1921; 1 female, Dennis, July 6, 1921; 1 female, Tishomingo, July 7, 1921; all paratypes from Mississippi taken by C. J. Drake.

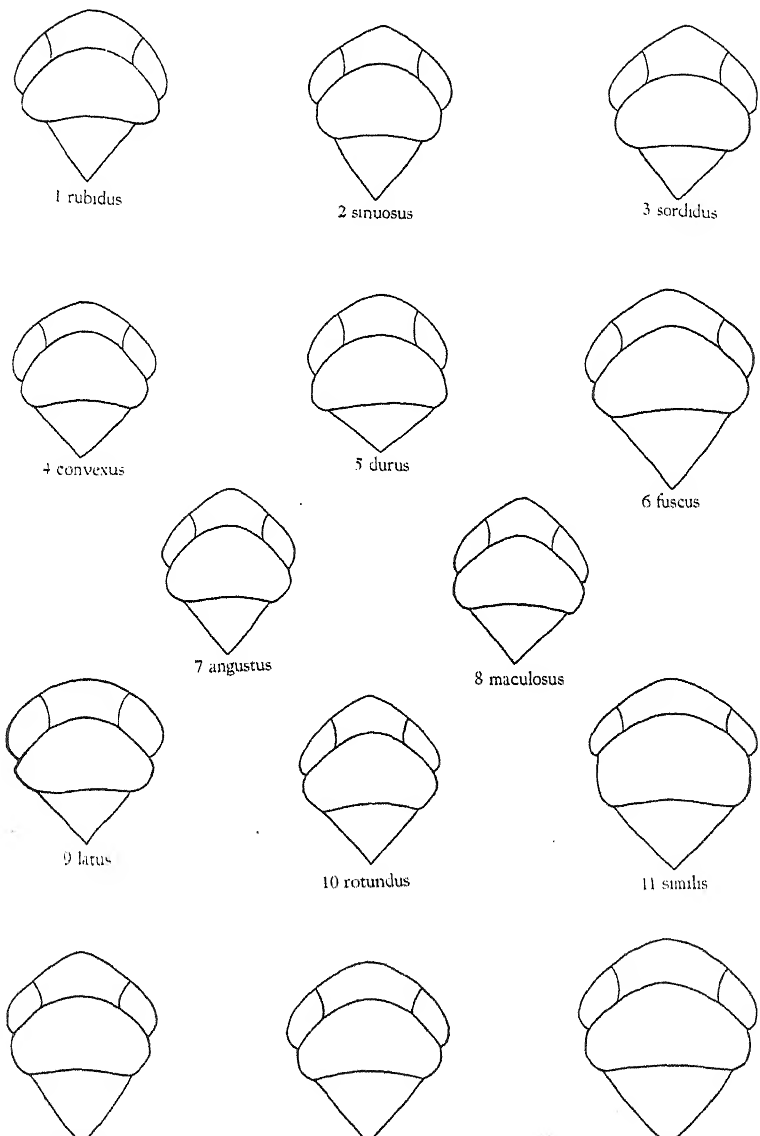
Types deposited in Snow Entomological Collection.

PLATE XXI

HEADS

1. rubidus.
2. sinuosus.
3. sordidus.
4. convexus.
5. durus.
6. fuscus.
7. angustus.
8. maculosus.
9. latus.
10. rotundus.
11. similis.
12. attenuatus.
13. pallidus.
14. latifrons.

PLATE XXI



1 rubidus
2 sinuosus
3 sordidus
4 convexus
5 durus
6 fuscus
7 angustus
8 maculosus
9 latus
10 rotundus
11 similis
12 attenuatus
13 pallidus
14 latifrons

PLATE XXII

EXTERNAL MALE AND FEMALE GENITALIA

1. pallidus—1a.
2. latifrons.
3. rotundus.
4. maculosus.
5. angustus—5a.
6. attenuatus—6a
7. sordidus.
8. rubidus—8a.
9. latus—9a.
10. sinuosus.
11. convexus.
12. durus.
13. fuscus.
14. similis—14a.

1—female. 1a—male.

PLATE XXII

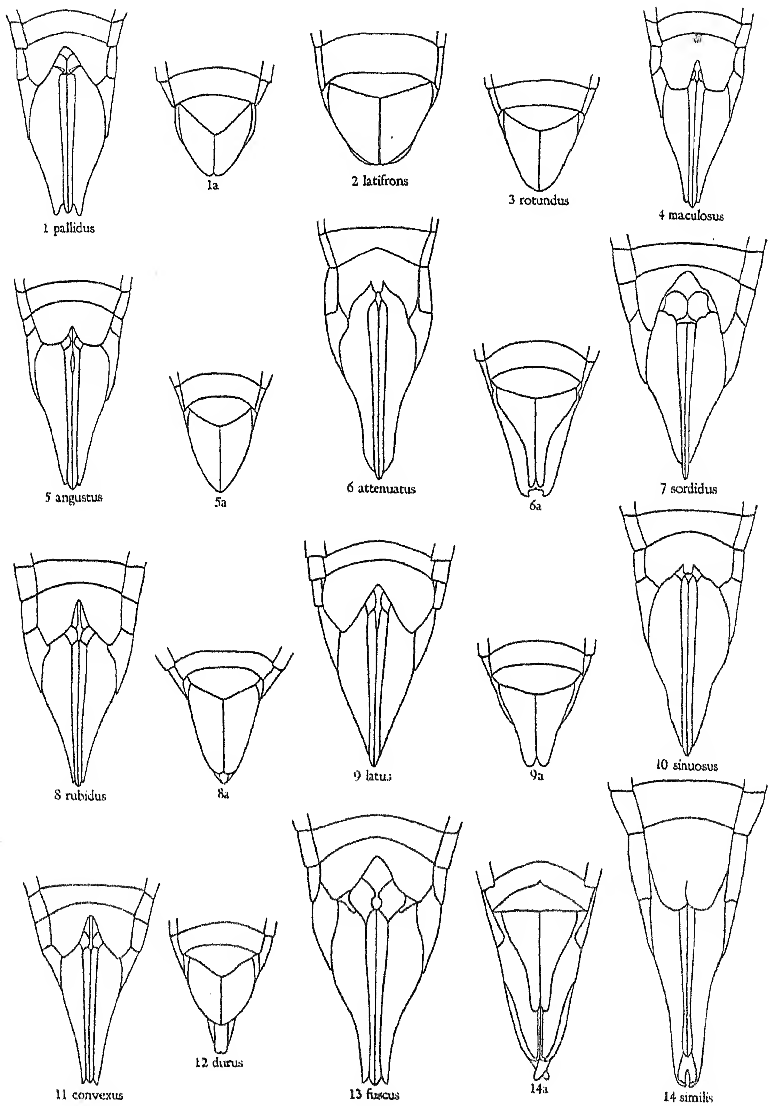

1 pallidus
1a
2 latifrons
3 rotundus
4 maculosus
5 angustus
5a
6 attenuatus
6a
7 sordidus
8 rubidus
8a
9 latus
9a
10 sinuosus
11 convexus
12 durus
13 fuscus
14a
14 similis

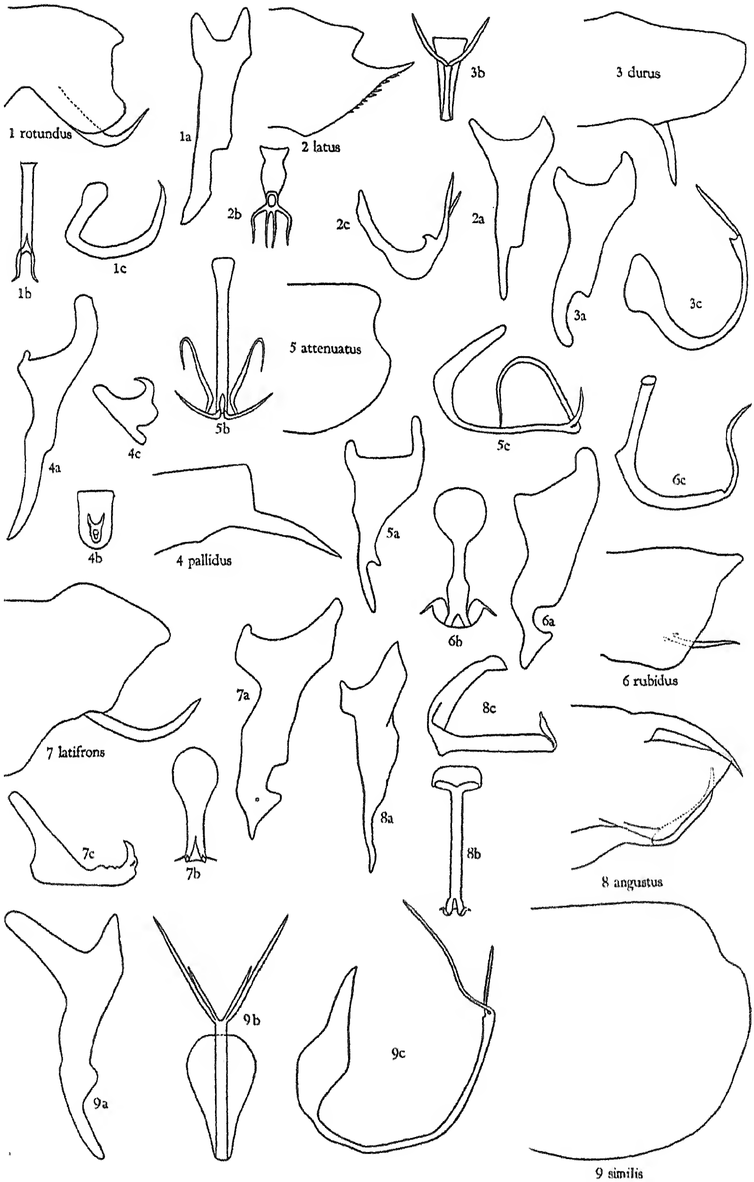
PLATE XXIII

INTERNAL MALE GENITALIA

1.	rotundus.	1a.	1b.	1c.
2.	latus.	2a.	2b.	2c.
3.	durus.	3a.	3b.	3c.
4.	pallidus.	4a.	4b.	4c.
5.	attenuatus.	5a.	5b.	5c.
6.	rubidus.	6a.	6b.	6c.
7.	latifrons.	7a.	7b.	7c.
8.	angustus.	8a.	8b.	8c.
9.	similis.	9a.	9b.	9c.

1—Side view of pygofer.
a—Dorsal view of style.
b—Dorsal view of oedagus.
c—Lateral view of oedagus.

PLATE XXIII



1 rotundus
1a
1b
1c
2 latus
2a
2b
2c
3 durus
3a
3b
3c
4 pallidus
4a
4b
4c
5 attenuatus
5a
5b
5c
6 rubidus
6a
6b
6c
7 latifrons
7a
7b
7c
8 angustus
8a
8b
8c
9 similis
9a
9b
9c

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SCIENCE BULLETIN

Vol. XXI.] March, 1933. [No. 5.

A New Species of Lizard from Mexico

EDWARD H. TAYLOR,
Department of Zoölogy, University of Kansas

Abstract: A species of skink, *Eumeces indubitus,* is described, related to *E. dugesi,* but differing in the character of the supraoculars and in color. The habitat of the species is the Mexican states of Michoacan, Mexico, and Morelos.

Among the lizards obtained in southern Mexico in the summer of 1932, by Hobart Smith and myself, is a medium-sized skink belonging to the genus *Eumeces,* which appears to be new to science. The form is represented in the collection by a series of thirty-three specimens, all from the southern part of the Mexican highland.

This southern Mexican region is of especial interest to the herpetologist, since the fauna, especially the lacertilian part of it, is rich and varied. Many of the genera are of the plastic type, and these register, as external scale and color characters, the effects of the environment.

Many species, too, seem to be of limited distribution. The fauna is such as to suggest a condition as might obtain if the species from a wide territory were herded together and driven into a much smaller teritory by some impelling environmental factor. In Mexico in the region south of the Tropic of Cancer are to be found not less than a dozen species of the genus *Eumeces,* representing most of the principal groups of the genus.

Eumeces indubitus sp. nov.

Type. No. 1731, Taylor-Smith collection: Collected July 9, 1932, on the Mexico-Cuernavaca highway, about forty miles southeast of Mexico City (kilometer 63), by Edward H. Taylor and Hobart Smith.

Diagnosis. A medium-sized, robust species; four supraoculars, the three anterior in contact with the frontal; the parietals inclosing small interparietal; one postmental; no postnasal; the subcaudals distinctly widened; seven upper labials, seven superciliaries; the seventh upper labial broadly in contact with the upper secondary temporal; primary temporal small, widely separated from lower secondary or tertiary; 24 scale rows about middle of body; 57 to 61 scales from occiput to above anus. Limbs moderately large, but failing to touch, even in young, when adpressed. Color above, olive to olive-brown with a short dorsolateral light line from rostral, the line disappearing on the shoulder; a narrow labial light line terminating at ear; no median light line or forking lines on the head.

Description of the Type. Adult male. Portion of rostral visible above, equal to about half the size of the frontonasal; internasals large, broadly in contact; frontonasal hexagonal, forming sutures with the loreals, and narrowly in contact with the frontal, forming its longest sutures with the prefrontals; later narrowly separated, forming sutures with first superciliary, both loreals and the anterior supraocular; frontal longer than its distance from the end of the snout, obtusely angular anteriorly, somewhat rounded posteriorly, somewhat narrowed in the middle, and only a little wider in the anterior part than in the posterior; four supraoculars, the anterior longer than wide with an area scarcely less than the fourth, the three anterior bordering the frontal; the frontoparietals larger than prefrontals, their common suture less than half their length; interparietal short and broad, inclosed behind by the parietals which are more than twice as long as their greatest width; two pairs of nuchals, the anterior somewhat the larger; nasal of moderate size, divided, the anterior part not as large as the posterior part with nostril; anterior loreal distinctly higher than long, higher than the posterior, which is considerably longer than high; seven superciliaries, the anterior less than one and one-half the size of the second; two subequal presuboculars; four posterior suboculars; primary temporal less than one-fourth the size of the upper secondary temporal; latter very broadly in contact with the seventh labial, the suture

more than half its length; seven upper labials, four preceding the subocular, which is low and elongate; seventh nearly double the size of the sixth and separated from the ear by a pair of small postlabials; tertiary temporal (the lower secondary presumably wanting) small; ear surrounded by 16 scales, the opening no larger than the first upper labial; six lower labials, the last elongate; mental large, deep, with a distinctly larger labial border than rostral; one azygous postmental; three pairs of chinshields, only one in contact; the postgenial large, bordered on its anterior inner edge by a scale wider than long; eye small, the lower eyelid with four or five enlarged opaque scales separated from the suboculars by at least three rows of granules; two or three median palpebral scales directly in contact with superciliaries, others separated by small granular scales. Scales on the dorsal surface and sides about equal in size, 24 rows about the middle of the body; 29 rows about neck behind ear; 30 about the constricted portion of the neck; 30 about body in axillary region; 15 rows about the base of the tail; 57 scales from occiput to above the anus; scales under the tail two and one-half to three times as broad as long; preanal scales large, broad, with two small, scarcely differentiated, scales on each side, the outer overlapping inner; lateral postanal scale not or scarcely differentiated; scales behind ear, about insertion of arm and in axillary region, on posterior side of femur, behind insertion of hind limbs, and along side of anus, with numerous distinct pits; two small auricular lobules.

Legs moderately large, separated when adpressed by a length of three or four scales; a very small area of granular axillary scales; wrist tubercle flat, well differentiated; several larger rounded tubercles on palm mixed with smaller tubercles; lamella formula, 5 : 8 : 11 : 10 : 7. Heel bounded by five large, flattened, tubercular scales, contiguous or overlapping one or two differentiated tubercles on sole; lamella formula, 5 : 9 : 11 : 13 : 9. Terminal lamella on toes not tightly bound about claws; no intercalated series of scales along the side of the fourth toe.

Color in Life. Above a light olive-brown, the head somewhat browner; darker flecks in the median part of each scale, more prominent posteriorly and tending to form dotted darker lines; a dorsolateral cream line, bordered on its inner edge with black, begins on rostral and continues on the side of the head and neck, but loses its identity on the shoulder; the two median scale rows are a shade darker than the two adjoining rows on each side; beginning on the

side of the head is a dark blackish or blackish-brown stripe, the color not uniform; each scale with light bronze areas, the black concentrated on the anterior part of the scales and tending to form an indistinct line on each scale row; a cream line beginning on the rostral passes along the lower edge of the first four labials and through the middle of the last three, the edges of the line clearly demarcated, terminates in the lower anterior corner of the ear; below the dark lateral stripe the ground color is grayish, and the scales have darker areas forming two or three very indistinct, dotted lines; lower labials light, bordered with darker; chin, lower side of neck and breast light, a few of the scales with darker flecks; hind legs darker than forelegs, each scale with lighter flecking; tail bluish gray, lavender blue below; lamellæ under toes dark.

Variation. The table, giving data from a part of the series available, shows the principal variation of this species as regards measurements and scale variation.

The number of scale rows is 24 save in two cases where there are but 22 rows; the number of upper labials is constantly 7; one specimen shows the third and fourth partially fused on one side. Only a single specimen shows the parietals separated, and this only very narrowly. Scales about the ear vary from 15 to 18, the numbers 15 and 16 most frequent; the higher numbers rarely occur. The scales from occiput to above anus vary from 57 to 61, 59 being twice as frequent as the other numbers. One postmental and no postnasal seem to be invariable characters. The seventh labial is invariably the largest, frequently double the size of the sixth; subdigital lamellæ under fourth toe 11-14, 12 and 13 being the most usual number. The number of the supraoculars is invariable. The temporals are surprisingly stable in character.

In color, the ground color varies in shade from darker to lighter. In younger specimens the color on the dark lateral stripe may be uniformly black. The character of the light lines does not vary, and is identical in the very young (31 mm.) and in adults. In the young the tail is a bright blue, and this color is usually retained by the adults, but with blackish or gray flecks breaking the uniformity. There is no trace of a lateral line from behind the ear along the side. The head in the young is never black. The dotted dark dorsal lines are more distinct in some specimens than in others.

Relationship. The relationship of this species is with *Eumeces dugesi*, despite the very striking difference in the character of the scales of the top of the head. It shows a parallel development with

Measurements and scale counts in *Eumeces indubitus* sp. nov.

Number	3593	1731	1671	1725	1728	1673	3598	1697	3600	1724	1696
Sex	♂	♂	♀	♂	♀	♂	♀	♀	♀	......	......
Snout to vent	66	64	62	64	64	63.5	58	54	41	37	32
Tail	108	......	......	105	......	......	......	......	66	57	47
Snout to forelimb	22	20.5	19	20	18	20	18	19	14	13	12
Axilla to groin	37	36	38	40	43	39	34	31	28	23	19
Width of head	11	10	10	10	9	9.8	8.4	8.2	7	7	6
Length of head	12	10.8	9.5	10	9.3	9.5	8.6	9.1	8	7.3	7
Width of body	13	12	12	13	12	12	10	10	8	7	6
Foreleg	15	13	12.2	12	12	14	11	12	9.5	8.5	8
Hind leg	20.2	19	17	18	18	19	15	15	12	11	10
Scale rows, body	24	24	24	24	24	24	24	24	24	22	22
Scales occiput to above anus	57	56	59	59	61	60	59	58	59	59	59
Upper labials	7	7	7	7	7	7	7	7	7	7	7
Supraoculars	4	4	4	4	4	4	4	4	4	4	4
Nuchals pairs	2	2	2	3	2	2	2	2	2½	2	2
Postmentals	1	1	1	1	1	1	1	1	1	1	1
Postnasals	0	0	0	0	0	0	0	0	0	0	0
Largest labial	7	7	7	7	7	7	7	7	7	7	7
Frontonasal touch frontal	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	No
Supraoculars touch frontal	3	3	3	3	3	3	3	3	3	3	3-2
Seventh labial touches upper sec. temporal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

that which has taken place in the *lynxe* group. *Furcirostris* with three supraoculars stands to *lynxe* as *dugesi* does to *indubitus*. However, it appears that in the two latter the different characters have become stabilized.

This new form may readily be separated from *Eumeces dugesi* by the character of four supraoculars, three touching the frontal, instead of three supraoculars, with only two touching the frontal. The contrast of color between the dorsal surface and the sides is much more pronounced in *dugesi* than in *indubitus;* the former often becomes yellowish bronze, and even silvery above. In all the specimens examined, thirty-three in all, there is no evidence that the characters separating the two forms overlap or intergrade.

The species may be more distantly related to *Eumeces brevirostris* Günther as suggested by the presence of a large seventh labial which makes contact with the upper secondary temporal.

Remarks. The present known distribution of this form is the Mexican states of Morelos, Mexico, and Eastern Michoacan. So far as is known, it is a high mountain form, as all specimens taken were found in the mountains in pine forest, under rocks or logs.

The food of this species, judged by stomach contents, consists wholly of small insects. An examination of the reproductive organs gave no clue as to whether the form is oviparous or ovoviviparous, since neither the ovaries nor uteri contained developing eggs. It is highly probable, however, that this, like its close relatives, *dugesi,* is ovoviviparous.

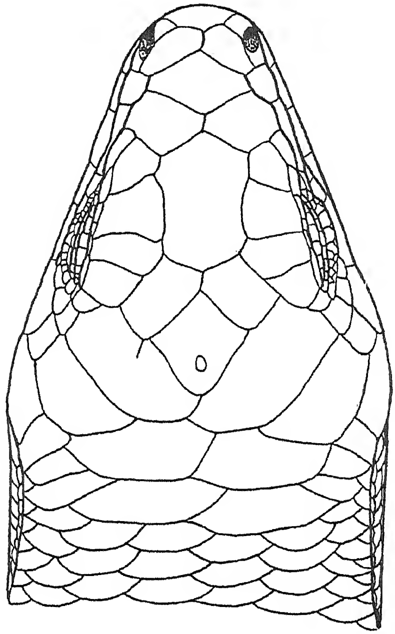
A single paratype (No. 1672) was presented to the Instituto de Biologia in Mexico City.

PLATE XXIV

FIG. 1. Enlarged drawing, lateral view of head of *Eumeces indubitus* sp. nov. (No. 1727, E. H. T. and H. S. Collection), which shows slight variation in scale characters from the type. Actual length of head, snout to end of parietals, 10 mm.

FIG. 2. Same, dorsal view.

PLATE XXIV



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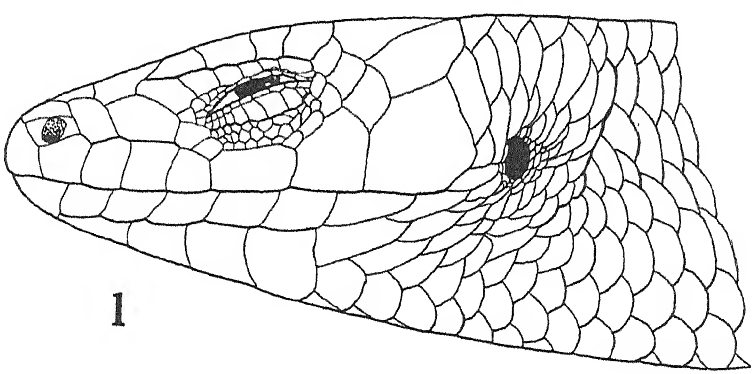

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PLATE XXV

FIG. A. Photograph of *Eumeces indubitus* (No. 1674, E. H. T. and H. S. Collection) from type locality. About actual size.

FIG. B. Photograph of the type specimen, about actual size.

PLATE XXV

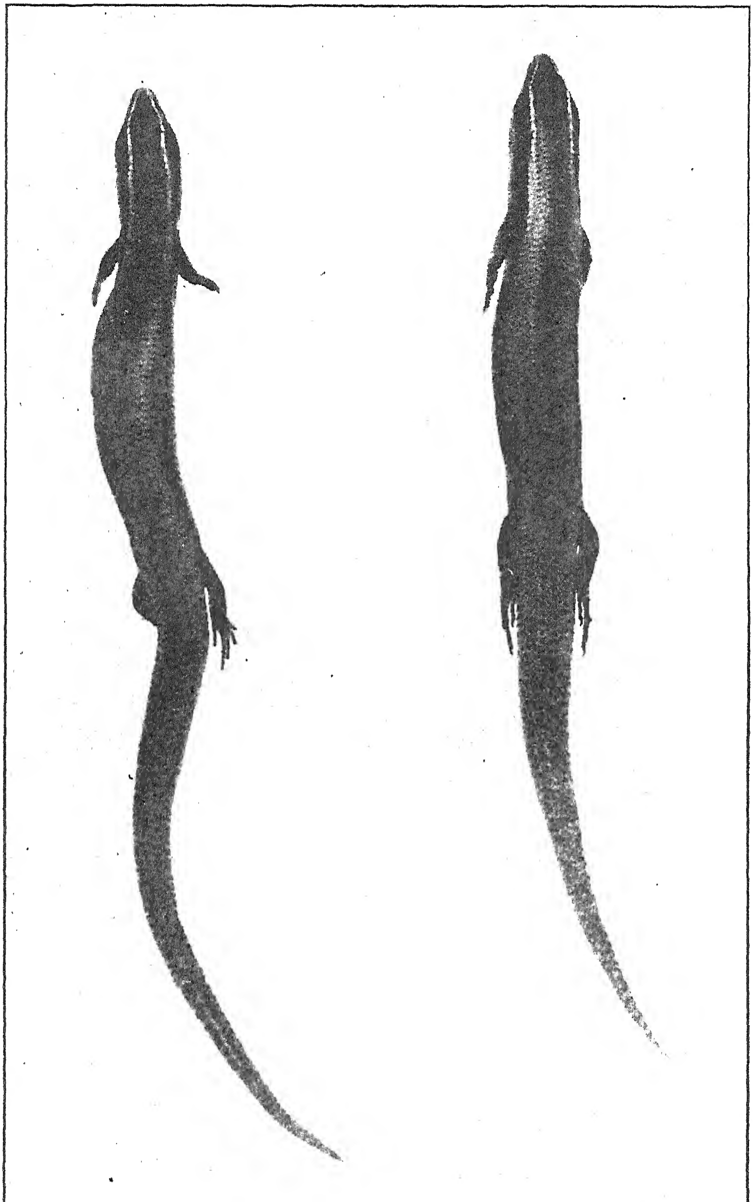

FIG. A. FIG. B.

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SCIENCE BULLETIN

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Observations on the Courtship of Turtles

EDWARD H. TAYLOR,
Department of Zoölogy, University of Kansas

ON October 2, 1932, about 150 turtles were received by the Department of Zoölogy, University of Kansas, from the ponds of the State Fish Hatchery at Pratt, Kansas. On receipt they were placed in a water tank, 4 feet by 18 feet, in a room in the basement of the biology building. This room had no outside source of light, and was kept at ordinary room temperature.

A few days after they arrived they were given a large feed of cooked table refuse consisting of fruits, meats, and vegetables, which they ate with great greediness. A census was taken on October 15, and the following specimens were present: 3 *Amyda mutica;* 14 *Chelydra serpentina;* 12 *Pseudemys elegans;* 35 *Kinosternon flavescens;* 80 *Chrysemys marginata belli.* Several small *Chrysemys* had died, or had been killed; and several had been partially eaten by the larger turtles. At this time a second large feed of cooked meat and vegetables, and raw lettuce was given them. All seemed to eat to the point of satiation.

On October 16 I observed a male of *Chrysemys* behaving in an unusual manner. He would start following a female of the same species, and by swimming faster would quickly overtake her; then, by whirling himself about in the water, he would start swimming backwards just in front of the female, who continued swimming straight ahead. Then the male would slow down, and as the female approached, he would push himself forward toward her, stretch out his arms full length forward, with the palms turned outward, the claws and fingers straightened, and vibrate them rapidly against the chin and lores of the swimming female. The fingers would touch the female from five to seven times during the continued vibration, which lasted perhaps less than one and a half seconds.

He would then withdraw his arms, and continue swimming backward ahead of the female. After an interim of from four to five seconds, this same action would be repeated in practically the same way. In this particular manner the act was repeated twelve times before they were interrupted by another turtle separating them by chance. Then the male turned, sought out another mate, and began the same type of courtship with her.

The turtles were watched at this time for nearly an hour, and eight courtships of this type were observed, although it was not impossible that the same individuals had taken part in more than one. The activity took place usually, but not invariably, at the surface of the water.

On October 17 the tanks were drained and cleaned and filled with fresh tap water, after which courtship began again, and as many as eight pairs were seen performing this strange series of maneuvers at the same time. It is probable that all the adult specimens were active by this time. The females seemed, throughout my observations, to be quite indifferent to the males, paying no more attention to one than to another of the males that approached them. When the lights were turned out the turtles all seemed to become quiescent; but shortly after turning on the lights, the whole tank would begin movement, and the courtships would be continued by the *Chrysemys*. The other species, however, remained quiet at the bottom of the tank. On the succeeding days occasional observations showed that the activity was continuing unabated.

On October 26 courtship was first noticed between members of the *Pseudemys elegans* group; and the procedure was almost identical with that of the *Chrysemys*, at least the differences are not easily described, save that the act was usually not repeated more than four or five times without a temporary cessation of activity. Up to this date no turtles were seen in copulation.

On October 27 a group of *Chrysemys* males that were actively carrying on a courtship were placed in a separate tank. At first they kept swimming about very rapidly as if seeking females. Their mode of sex recognition could not be determined, save that when a male was approached, and the arms were extended, the second male would thrust his arms forward, and the two would abandon each other. My observations were interrupted, and I left, leaving the room lighted; on my return three pairs of males were keeping up the play with each other. Each kept the same approximate position, moving back a few inches; then each advancing, vibrated the

fingers against the fingers of the other. On occasion this would be kept up for two or three minutes.

On October 28, shortly after the room was lighted, the males again became active; and after a considerable amount of swimming about, three pairs of males were again observed continuing the courtship. When three females were placed in the tank, two and even more males might attempt to engage her attention. On this date a male *Kinosternon flavescens* was observed attempting copulation with a small female *Chrysemys*. The shell of the female was held by all four feet of the *Kinosternon* from a dorsal position. The latter would lift his body and strike the shells together.

On October 29 a pair of *Kinosternon* were observed in copulation, and two other pairs were observed clasping and apparently tapping their bodies together. Here the semiprehensile tail with its spine-like tip serves as a very efficient grasping organ. When clasping, the male holds the female's shell by all four of his feet and his tail. In copulation the hold of the front feet is loosened, and the male stands erect.

Two *Chelydra serpentina* were seen on November 11, their heads close together in shallow water; they appeared to be gulping in water and then forcing it through their nostrils, causing a "boiling" of the water in two areas above their heads at the surface. This was continued for about ten minutes, their heads close together, sometimes touching. After cessation of this behavior, I determined that a male and a female were involved. By this date the activity of the other forms had practically ceased, and no others were observed in copulation, except for a single pair of *Chelydra*, which were found in copulation November 4; but these became disengaged almost as soon as they were discovered, and before accurate observations could be made. A week later all the specimens were preserved. The *Amyda mutica* were all females; no sexual activity was observed in this species.

That the observed behavior of these forms constitutes the typical courtship behavior can scarcely be questioned, even though it may have been induced by high temperature and heavy feeding at a season of the year when it does not normally occur. The peculiar courtship pattern is essentially identical in *Chrysemys marginata belli* and *Pseudemys elegans*, and may likewise be the same in other aquatic genera of the family Testudinidæ.

I am uncertain whether the curious behavior of *Chelydra serpentina* is to be considered as a courtship activity or not. It was observed only on a single occasion.

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VOL. XXI.] MARCH, 1933. [No. 7.

A New *Bassariscus* from the Lower Pliocene of Nebraska

CLAUDE W. HIBBARD,
The University of Kansas Museum of Vertebrate Paleontology

ABSTRACT: A new carnivore, *Bassariscus ogallalæ,* is described from a specimen in the University of Kansas Museum of Vertebrate Paleontology from the type locality of the Ogallala formation, Ogallala, Nebraska. Comparison is made with other known fossil species of the genus.

THROUGH the courtesy of Dr. H. H. Lane, acting curator in charge of the Department of Vertebrate Paleontology of the University of Kansas, I have been given the opportunity of studying and describing the right lower jaw of a new species of *Bassariscus.*

Fossil remains of *Bassariscus* are rare, since there have been reported heretofore only three specimens of *B. antiquus* Matthew and Cook; one from the Upper Miocene of western Nebraska, one from the Upper Miocene of western Nevada, and another from the Pliocene of San Joaquin Valley of California. There is but a single known specimen of *B. parvus* Hall from the Upper Miocene of west central Nevada.

The specimen herein reported is from near the top of the Lower Pliocene. It was collected on the Feldt Ranch, approximately two miles east and one-half mile north of the town of Ogallala, Nebraska.

The specimen was obtained during the summer of 1931 by William K. McNown and myself while making a survey of the Lower Pliocene through southern Nebraska, western Kansas and western Oklahoma for the Department of Vertebrate Paleontology of the Muesum of the University of Kansas.

Bassariscus ogallalæ sp. nov.

(Plate XXVI; figs. 1-3)

Type. No. 3749, University of Kansas Museum of Vertebrate Paleontology. Right lower jaw bearing P_3, P_4, M_1 and M_2, with alveoli of I_3, C, P_1 and P_2, lacking angle, condyle and coronoid process.

Horizon and Type Locality. From the type locality of the Ogallala formation and 35 feet below the top of the local section, Lower Pliocene, approximately two miles east and one-half mile north of the town of Ogallala, Keith county, Nebraska, on the Feldt ranch. (The correlation was made by M. K. Elias, member of the Kansas Geological Survey.)

Diagnosis. See Table 2 of Measurements and Ratios. The length of M_1 and M_2 are the same, making the ratio, length of M_1 to the length of M_2, 100 or 1. The ratio, length of the talonid of M_1 to the length of the trigonid of M_1; and the ratio length of M_1 to the length of M_2 are greater than in any other known species of *Bassariscus;* the length of the trigonid of M_1, and the ratio, width of M_2 to the length of M_2 are less.

Description of Type. The jaw is of an adult, as is shown by the worn cusps. P_4 has a well-developed accessory cusp posterior and lateral to the protocone, which exceeds in size any examined of the living species, *Basariscus astutus flavus* Rhoads. There is no trace of an accessory cusp on P_3. M_1 has strong and well-developed cusps. M_2 has a well-developed paraconid, greatly exceeding the protoconid in size. The entoconid, hypoconulid, and hypoconid are distinct and well developed. The distance across M_2 from the top of the entoconid to the top of the hypoconid is 3.5 mm. The anterior mental foramen is larger and is located more posteriorly than that of *B. astutus flavus.* It is below the middle of P_2, while in *B. astutus flavus* it is below the anterior root of P_2. The posterior mental foramen is smaller than that of *B. astutus flavus* and is below the posterior root of P_3 and lies slightly dorsad to the anterior mental foramen, a condition not observed in *B. astutus flavus.* The inferior dental foramen is larger, and is situated more posterior to the anterior surface of the ascending ramus, although closer to M_2 than in *B. astutus flavus.* The nearness of the dental foramen to M_2 is accounted for by the large development of that tooth. The jaw is deeper, thicker, and heavier, though shorter, than that of *B. astutus flavus.*

Remarks. The comparison of *B. ogallalæ* with that of other fossil *Bassariscus* shows the following similarities and differences. (See Table 1.) Hall [1] has placed *Probassariscus antiquus matthewi* Merriam[2] in synonomy with *Bassariscus antiquus* Matthew and Cook.[3] A comparison of *B. ogallalæ* with *B. antiquus* shows a slightly smaller M_1 with greatest difference in the width of the talonid, which is an average of 0.6 mm. smaller. The ratio, width of the talonid of M_1 to the length of M_1 is less than in *B. ogallalæ* and does not fall within the limits of individual variation of *B. antiquus*. *B. ogallalæ* may be distinguished from *B. antiquus* by the size of M_2. M_1 and M_2 of *B. ogallalæ* are the same length, making the ratio, length of M_1 to the length of M_2, 100 or 1. The ratio, width of M_2 to the length M_2 is 42.9, the smallest known ratio of any *Bassariscus*.

Bassariscus ogallalæ is distinguished from *Bassariscus parvus* Hall [4] by the ratio, length of the talonid of M_1 to the length of the trigonid of M_1, which is 10.7, greater in *B. ogallalæ*. Another outstanding difference between *B. ogallalæ* and *B. parvus* is the crowded condition of the premolars of the latter, which does not occur in *B. ogallalæ*.

The specimen is named for the Ogallala formation, from which it was collected.

1. Hall, E. R., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 16, No. 11, p. 437, March 17, 1927.
2. Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 6, p. 246, Part 2, Sept. 16, 1911.
3. Matthew and Cook, Bull. Am. Mus. Nat. Hist., Vol. 27, p. 337, Sept. 3, 1909.
4. Hall, E. R., op. cit., p. 435.

TABLE I

Measurements (in millimeters) and ratios of measurements of M_1 and M_2 of the fossil forms of *Bassariscus*.

U. C. C. V. P., University of California Collection of Vertebrate Paleontology.
A. M. N. H., American Museum of Natural History.
K. U. M. V. P., Kansas University Museum of Vertebrate Paleontology.
C. I. T. C. V. P., California Institute of Technology Collection of Vertebrate Paleontology.

Name, catalogue number and collection.	LOCALITY.	M_1 length	M_1 length of talonid	M_1 length of trigonid	Ratio, length of talonid of M_1, to length of trigonid of M_1	M_1 width of talonid	Ratio, width of talonid of M_1, to length of M_1	M_2 length	Ratio, length of M_1 to length of M_2	M_2 width	Ratio, width of M_2 to length of M_2
Bassariscus antiquus:											
*12539 U. C. C. V. P.	Virgin Valley, Nevada, Upper Miocene	7.5	3.2	4.3	74.4	3.7	49.3	5.8	77.3	3.2	55.2
*13860 A. M. N. H.	Sious County, Nebraska, Upper Miocene	7.5	3.2	4.3	74.4	3.5	46.7	5.7	76.0	2.8	49.1
†66 C. I. T. C. V. P.	Kern County, California	7.5	3.2	4.3	74.4	3.6	48.0	....	....	....	....
Bassariscus parvus:											
*19768 U. C. C. V. P.	Stewart Valley, Nevada, Upper Miocene	6.9	2.7	4.2	64.3	3.1	44.9	....	....	....	....
Bassariscus ogallalæ:											
3749 K. U. M. V. P.	Keith County, Nebraska, Lower Pliocene	7.	3.	4.	75.	3.	42.9	7.	100.	3.	42.9

* Taken from Hall. Univ. Calif. Publ. Bull. Dept. Geol. Vol. 16, No. 11, p. 447, March 17, 1927.
† Taken from Hall. Journ. Mammalogy, Vol. 11, No. 1, February, 1930.

EXPLANATION OF MEASUREMENTS (HALL)[5]

M_1, length; taken at cingulum; thus, usually, but not always, the greatest length.
M_1, length of talonid; taken on lateral side of tooth from posterior base of protoconid to posteriormost extension of talonid.
M_1, length of trigonid; taken from posterior base of protoconid to anterior end of tooth at cingulum.
M_1, width of talonid; taken from indentation on lateral side of tooth just behind the protoconid to opposite side of tooth and perpendicular to longitudinal axis of tooth.
M_2, length; taken from cingulum at posterior end of tooth to most anterodorsal point of tooth, usually but not always, greatest length.
M_2, width; taken from indentation on lateral side of tooth just behind the protoconid to opposite side of tooth and perpendicular to longitudinal axis of tooth.

TABLE 2

Measurements and Ratios of *Bassariscus ogallalæ*

The ratios given in the table are the actual ratios multiplied by 100.

	mm.
Length from posterior border of canine aveolus to posterior border of M_2	29
Length of P_4 to M_2, inclusive	18.2
Length of P_3 to M_2, inclusive	22
Length of P_3 and P_4, inclusive	8
Length of P_3	4
Breadth of P_3	2
Breadth of P_4	2.9
Length of P_4	4.5
Length of M_1	7
Breadth of M_1	3.5
Length of M_2	7
Breadth of M_2	3
Length of talonid of M_1	3
Length of trigonid of M_1	4
Ratio, length of talonid of M_1 to length of trigonid of M_1	75
Width of talonid of M_1	3
Ratio, width of talonid of M_1 to length of M_1	42.9
Ratio, length of M_1 to length of M_2 100 or	1
Ratio, width of M_2 to length of M_2	42.9
Length of alveolus of canine	3
Length of alveolus of P_2	3.5
Length of alveolus of P_1	2
Breadth of alveolus of P_1	1.5
Breadth of alveolus of P_2	1.5
Depth of jaw beneath M_1	8

5. Hall, E. R., Op. Cit. p. 445.

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Two New Species of *Cœlacanthus* from the Middle Pennsylvanian of Anderson County, Kansas

CLAUDE W. HIBBARD
Kansas University Museum of Vertebrate Paleontology

ABSTRACT: Two new species of Cœlacanthid fishes, *Cœlacanthus newelli* and *Cœlacanthus arcuatus*, are described from specimens in the University of Kansas Museum of Vertebrate Paleontology. Both species are from the Rock Lake shale, Stanton formation, Missouri series, near the top of the Middle Pennsylvanian of Mid-Continent, Anderson county, Kansas. A comparison is made with other known species of the genus from the Pennsylvanian.

THROUGH the courtesy of Dr. H. H. Lane, curator in charge of the Department of Vertebrate Paleontology of the Kansas University Museum, I have been given the opportunity of studying and describing the remains of two apparently new species of fish of the genus *Cœlacanthus*.

The remains of *Cœlacanthus* are known from only a few localities in North America. *C. robustus*, *C. ornatus*, and *C. elegans* were described by Newberry[1] from the Pennsylvanian (Linton) of Ohio, U. S.; *C. exiguus*, by Eastman[2] from the Pennsylvanian (Mazon creek) of Illinois, U. S.; *C. welleri*, by Eastman[3] from the Mississippian (Kinderhook) of Iowa, U. S.; *C. banffensis*, by Lambe[4] from the Triassic? (Upper Banff) of Alberta, Canada.

To my knowledge the above records include all localities where *Cœlacanthus* has been found to occur in North America, except the

1. Newberry. Proceedings of the Academy of Natural Science of Philadelphia. Vol. VIII, 1856, p. 98.
2. Eastman, C. R. Jour. Geol., X, p. 538.
3. Eastman, C. R. Jour. Geol., XVI, p. 358.
4. Lambe, L. M. Trans. Roy. Soc. Canada, X, sec. IV, p. 38.

specimen reported by Eastman in the Proceedings of the U. S. National Museum, vol. 52, p. 271, where he says, "A supposed new form has recently been discovered by Prof. E. H. Barbour in the Coal Measures of Nebraska."

The specimens herein reported are from near the top of the Middle Pennsylvanian of Mid-Continent, Stanton formation, Rock Lake shale member, from the SW¼ of SE¼ of sec. 32, T. 19 S, R. 19 E, on the Bradford Chandler farm, Anderson county, Kansas. (The Rock Lake shale was identified by the Kansas State Geological Survey.)

We are greatly indebted to Mr. Bradford Chandler, upon whose farm the specimens were taken, for the permission to collect, and the kindness shown us while working at the quarry.

Cœlacanthus newelli sp. nov.

(Plate XXVII, figs. 2-3)

Type. No. 786 F. University of Kansas Museum of Vertebrate Paleontology. Nearly complete skeleton, lacking pectoral fins, with crushed skull and only a few complete scales.

Horizon and Type Locality. From the Rock Lake Shale, Stanton formation, Missouri series, near the top of the middle Pennsylvanian of Mid-Continent. Collected on the SW¼ of SE¼ of sec. 32, T. 19 S, R. 19 E, of the Bradford Chandler farm, Anderson county, Kansas.

Diagnosis. The exposed ridged surface of the scale is elongate, resembling somewhat a truncated cone. It is 1.74 mm. long and 1.39 mm. wide at the base of the exposed surface. The scales have an average of 9 ganoid ridges each. The ridges do not meet at the posterior end in an acute angle, but converge slightly toward the median ridge near the posterior end and then straighten out again to terminate slightly posterior to the median ridge.

Description of Type. The specimen is nearly complete. The skull is crushed, leaving only the jugal plate in place and perfect enough for detailed study. The pectoral fins are missing. The fish was so crushed in preservation as to push the pelvic fin upward onto the side of the body and to bring the opposite pelvic fin into view and nearly into the original position of the first. The fish was deposited upon a plant (4) four branches of which cross the skeleton at right angles. Both the positive and negative of the fish were collected. The skull is missing from the positive of the shale. (Plate XXVII, fig. 2.)

The length of the fish from the snout to the tip of the caudal rays is 115 mm.

Only a few fragmentary skull bones are present. Some are ornamented with short, narrow, ganoid ridges; others with closely set tubercles. There is no trace of teeth, probably due to the crushed condition of the dentary and maxillary. An outline of the opercular region is shown, but the operculum is missing.

The jugal plate is 16 mm. long and 4.5 mm. wide. It is ornamented with fine, unevenly spaced, ganoid ridges running anteroposteriorly, but having a tendency to meet at the center of the plate, as though radiating from this central point.

The posterior portion of the skeleton is not distorted. The depth of the body anterior to the attachment of the anal fin is 20 mm.

The anterior dorsal fin is badly crushed, bringing the rays close together. Only 6 rays are distinguishable. These are twice as wide at their bases as the rays of any of the other fins. There is a distance of 26 mm. from the anterior base of the anterior dorsal fin to the anterior base of the posterior dorsal fin. The posterior dorsal fin is slightly anterior to the anal fin. Only 8 rays can be counted. The largest is 11.5 mm. long. This fin furnishes no suggestion of a lobate condition.

The caudal fin consists of 24 principal rays, 12 above and 12 below. The longest rays are 26.5 mm. in length. The supplementary caudal fin at the widest is 4 mm., and is 17 mm. long. There are present 6 supplementary caudal rays, 3 above and 3 below.

The anal fin is nearly perfect. It consists of 8 rays, the longest being 7 mm. The anal fin is the smallest of the fins and gives no suggestion of being lobate. It is slightly posterior to the anterior attachment of the posterior dorsal fin.

The pelvic fin is composed of at least 20 rays. This fin shows a strongly lobate condition. The length of the lobe of the pelvic fin is 6 mm. This fin is located posterior to the anterior attachment of the anterior dorsal fin. The distance from the anterior base of the anal fin is 25.5 mm. Both the pectoral and pelvic arches appear to be missing.

The anterior portion of all the fin rays present is jointed, but shows no evidence of denticles.

The cycloid scales of this fish are covered on the exposed surface by ganoid ridges. The exposed ridged surface of the scales is 1.74 mm. long and 1.39 mm. wide at the base of the exposed surface. (Plate XXVII, fig. 3.) The scales seem to be of uniform shape, having the same pattern of ornamentation where present through the different regions. The exposed ridged surface of the scales is

elongate, resembling somewhat a truncated cone. The scales have an average of 9 ganoid ridges each. The ridges do not meet at the posterior end in an acute angle, but converge slightly toward the median ridge near the posterior end and then straighten out again to terminate slightly posterior to the median ridge.

Remarks. The comparison of *Cœlacanthus newelli* with the other forms of *Cœlacanthus* from the Pennsylvanian follows: *Cœlacanthus newelli* differs from *C. ornatus* Newberry in that the raised ganoid ridges of the scales are *not* parallel; furthermore, the anal fin rays of the former number 8 instead of 6. Newberry [5] states, "*Cœlacanthus ornatus* may be readily identified by its small size, relatively large cranial tubercles, and very thin, delicate scales on which the raised lines are parallel and do *not* converge as in *C. elegans* and *C. robustus.*" *Cœlacanthus newelli* differs from *C. elegans* Newberry and *C. robustus* Newberry in that the exposed surface of the scales is not circular in outline and is not ornamented by converging ganoid ridges. The number of ridges in *C. newelli* averages 9, while in *C. elegans* the average is at least 20. It may be at once distinguished from *C. exiguus* Eastman by its larger size.

The *Cœlacanthus* here called *newelli,* is so named in honor of Norman D. Newell, who was a graduate student in the Department of Geology at the University of Kansas at the time he discovered the fossil-bearing pocket in the Rock Lake Shale, while doing field work on his problem in the summer of 1931.

Cœlacanthus arcuatus sp. nov.

(Plate XXVI, fig. 8; Plate XXVII, fig. 1)

Type. No. 787F. University of Kansas Museum of Vertebrate Paleontology. Caudal region of a cœlacanthid fish just posterior to anal fin, with anterior caudal fin rays and the greater part of the supplementary caudal fin missing.

Horizon and Type Locality. From the Rock Lake Shale, Stanton formation, Missouri series, near the top of the middle Pennsylvanian of the Mid-Continent. Collected on the SW¼ of SE¼ of sec. 32, T. 19 S., R. 19 E, on the farm of Bradford Chandler, Anderson county, Kansas.

Diagnosis. The exposed ridged surface of the scales is shaped like a Gothic arch in outline. It is ornamented with an average of 12 to 14 ganoid ridges which are slightly heavier than those of *C.*

5. Newberry, Paleozoic Fishes of North America, U. S. Geol. Survey, Vol. XVI, p. 227.

newelli. The ridges converge toward the median ridge at the posterior end of the scale, but do not join the median ridge. The exposed ridged surface of the scales is 2.17 mm. long and 2.16 mm. wide. (Plate XXVII, fig. 1.)

This *Cœlacanthus* may at once be distinguished from all other forms studied, by the shape of the scale with its constant pattern and number of strong ganoid ridges.

Description of Type. The specimen herein described came from the Rock Lake Shale, closely associated with *Cœlacanthus newelli,* but approximately 18 inches above the former. The specimen consists of the caudal region just posterior to the anal fin, with the tips of the caudal rays and the greater part of the supplementary caudal fin missing. This caudal region represents a fish nearly twice as large as *C. newelli.* (Plate XXVI, fig. 8.)

There are 24 principal caudal fin rays, 12 above and 12 below. The supplementary caudal fin is 8 mm. wide. There are 12 rows of cycloid scales just anterior to the attachment of the caudal rays, running parallel to the median line. The width of the caudal region just anterior to the attachment of the caudal rays is 24 mm.

Remarks. The significance of the number of ganoid ridges and the shape of the scales in *Cœlacanthus* can only be known with certainty when sufficient material has been collected from one locality. It is possible that age and relative maturity may profoundly affect the number and arrangement of the ridges, as well as the shape of the scale. A large series of specimens will be necessary in order to indicate definitely which of these characters are due to age, and which to speciation.

The figures of the scales of *C. elegans* (Plate XXVI, fig. 7) and *C. lepturus* (Plate XXVI, figs. 4, 5, 6 and 9) have been given for comparison. They were taken from the Geological Survey of the United Kingdom, Decade XII, 1866, after Huxley.

The *Cœlacanthus arcuatus* is so named because of the shape of the scale which resembles so closely a Gothic arch in miniature.

The first material collected from the Rock Lake Shale by the Department of Vertebrate Paleontology during the spring and summer of 1932, belongs to the genus *Cœlacanthus*. Besides the material described, there were secured many unassociated scales and fin rays; also one pelvic fin and many skull fragments.

PLATE XXVI

FIGS. 1-3. *Bassariscus ogallalæ.* Type: No. 3749, University of Kansas Museum of Vertebrate Paleontology. $\times$ 2.27 natural size. (1) Lateral view. (2) Occlusal view. (3) Lingual view.

FIGS. 4, 5, 6 and 9. Scales of *Cœlacanthus lepturus,* magnified. After Huxley.

FIG. 7. Scales of *Cœlacanthus elegans,* magnified. After Huxley.

FIG. 8. *Cœlacanthus arcuatus,* natural size. Type: No. 786F, University of Kansas Museum of Vertebrate Paleontology. Negative by Prof. M. K. Elias.

PLATE XXVI

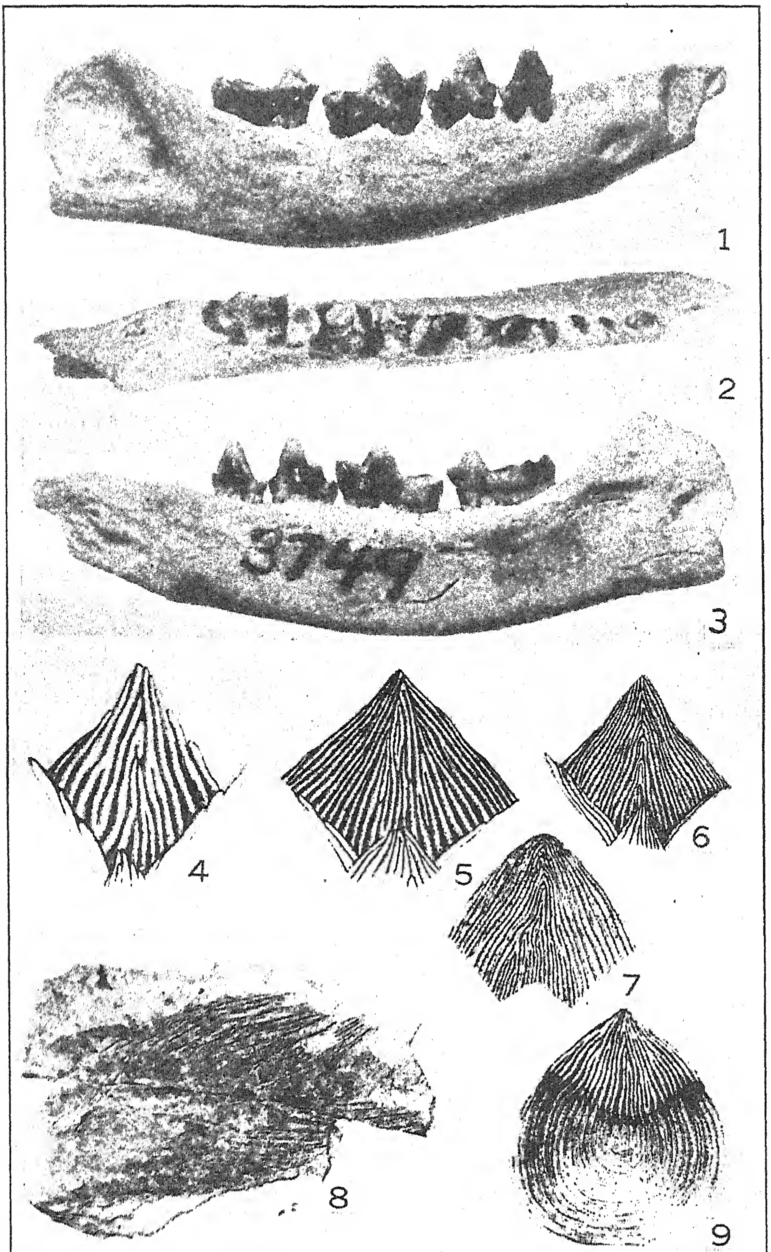


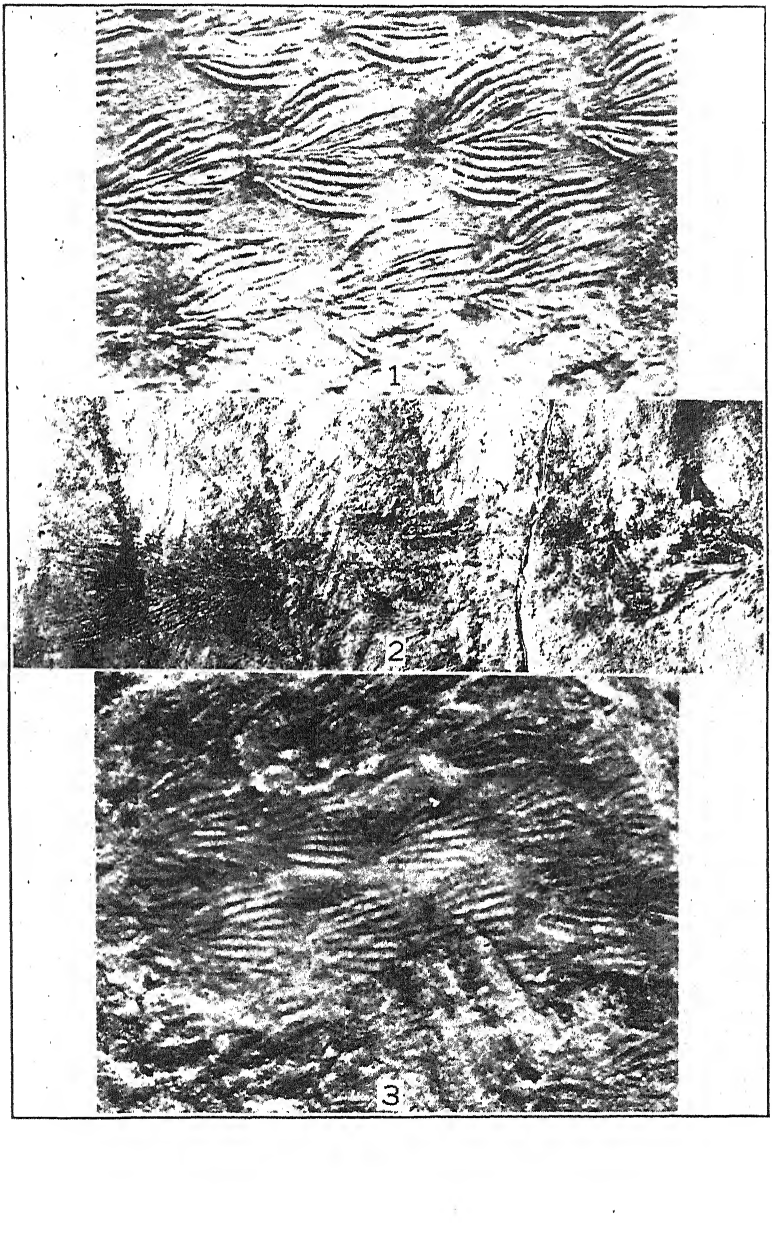
PLATE XXVII

FIG. 1. Scales from the caudal region of the type No. 787F, *Cœlacanthus arcuatus*. × 11.5.

FIG. 2. *Cœlacanthus newelli;* natural size. Type No. 786F, University of Kansas Museum of Vertebrate Paleontology. Negative by Prof. M. K. Elias.

FIG. 3. Scales from region near midline anterior to anal fin, of the type No. 786F, *Cœlacanthus newelli*. × 11.5.

PLATE XXVII



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Cephalopods of the Pierre Formation of Wallace County, Kansas, and Adjacent Area

MAXIM K. ELIAS

TABLE OF CONTENTS

ABSTRACT: The paper is devoted chiefly to the description and to the discussion of stratigraphic value of some of the Upper Cretaceous ammonoids of the *Baculites* and *Scaphites* group in western Kansas and adjacent part of Colorado.

The following new names are introduced:

Baculites pseudovatus Elias, n. sp.
Baculites pseudovatus var. *A.* Elias, n. var.
Baculites compressus var. *reesidei* Elias, n. var.
Baculites compressus var. *corrugatus* Elias, n. var.
Baculites clinolobatus Elias, n. sp.
Baculites meeki Elias, n. sp.
Discoscaphites nicolleti var. *saltgrassensis* Elias n. var.

The specific name *compressus* Say is very narrowly restricted to the topotype of the species *Baculites compressus* as described by Meek (1854, 1876). *Scaphites nodosus* var. *plenus* Meek is removed from the *Acantoscaphites nodosus* group and is elevated to the rank of species of the genus *Scaphites* sensu stricto: *Scaphites plenus* (Meek).

INTRODUCTION

AMMONITES of both coiled and uncoiled types are among the most abundant fossils in the Pierre of northwestern Kansas. Some genera and species of this order are the most important horizon-markers of the local subdivisions of the Pierre, and a few of them are of great importance for the correlation of the formation with the contemporaneous beds in eastern North America and Europe. Owing to this fact the writer devoted more time and care to the study of these invertebrates than of the other marine fossils of the formation. It is intended to describe the latter in a forthcoming separate paper.

The writer wishes to acknowledge valuable suggestions and criticism by Dr. R. C. Moore and Dr. J. B. Reeside, Jr., which helped considerably in precise identification and in elaborating the description of the species.

STRATIGRAPHIC RANGE OF THE DESCRIBED SPECIES

In the following tables the stratigraphic distribution of the ammonites herein described and a few others are shown. The distribution in space and time of the most important of these forms is also shown on the stratigraphic table of the geological report on Wallace county (Bull. 18, State Geological Survey of Kansas, 1931).

METHOD OF DRAWING SUTURES OF *BACULITES* AND OTHER AMMONOIDEA

In preparing the sketches of the sutures of *Baculites* and other Ammonoidea of the Pierre two methods were used. The larger sutures were traced directly on cellophane, which was wrapped around a portion of a fossil. In order to add visibility and avoid mistakes in tracing, the space between two neighboring sutures was painted with black India ink. A fine drafting pen was used for painting the minute dentations of the sutures. Cellophane is preferable to other transparent material (celluloid film, wax paper, tracing cloth, etc.) because it is perfectly transparent, and, being soft and flexible, can be pressed more tightly against the uneven surface of the variously sculptured molds of ammonoids. The India ink sticks to cellophane fairly well, and fine lines can be drawn on it. However, when drawing a line over those places where the cellophane is not quite firmly pressed against the surface of the fossil, one inevitably scratches the soft tissue with the sharp point of

	Sharon Springs shale member		Weskan shale member		Lake Creek shale member		Salt Grass shale member		Undifferentiated shale	Beecher Island shale member
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Middle		
Baculites aquilænsis var. *separatus* Reeside		x(?)								
Baculites ovatus var. *haresi* Reeside				x						
Baculites pseudovatus Elias, n. sp.				x	x					
Baculites pseudovatus var. A Elias, n. var.							x	x		
Baculites compressus Say, emend. Meek				x	x	x				
Baculites compressus var. *reesidei* Elias, n. var.					x	x	x	x		
Baculites compressus var. *corrugatus* Elias, n. var.						x	x			
Baculites clinolobatus Elias, n. sp.										x
Baculites grandis Hall and Meek									x	x
Baculites meeki Elias, n. sp.										x

	Sharon Springs shale member		Weskan shale member		Lake Creek shale member		Salt Grass shale member			Undiffer-entiated shale	Beecher Island shale member
	Lower	Upper	Lower	Upper	Lower	Upper	L	M	U		
Heteroceras tortum Meek & Hayden		x									
Placenticeras meeki Boehm			x	x	x						
Acanthoscaphites nodosus Owen				x	x	x					
Acanthoscaphites nodosus var. *brevis* Meek				x	x	x	x				
Acanthoscaphites nodosus var. *quadrangularis* Meek & Hayden				x	x	x	x				
Acanthoscaphites (?) *reesidei* Wade							x				
Scaphites plenus Meek							x				
cf. *Discoscaphites constrictus* var. *tenuistriatus* (Kner)			x			x					
Discoscaphites nicolleti var. *saltgrassensis* Elias, n. var									x		
Discoscaphites conradi (Morton)											x
Discoscaphites abyssinus (Morton)											x

the pen. Owing to this the lines soon become too heavy to express the finer details of the sutures. The writer found that it is much safer and more convenient not to trace on cellophane the suture lines themselves, but to ink in the space on one side of a suture.

The next operation is the final tracing from the cellophane drawing. Due to slight warping of the cellophane painted with India ink, the use of a light-table (table with glass top illuminated from below) is recommended. If desirable the cellophane copy can be enlarged by photography and the final tracing of the suture can be made from the photograph. In view of the desirability of having the drawings two times larger than the proposed size of printed illustrations the enlargement by photography is ordinarily preferable.

For the tracing of very small and complicated sutures the method of direct tracing on cellophane is too crude. For drafting of the sutures of juvenile stages of *Baculites* and, also, of the sutures of smaller coiled scaphites, the writer used a camera-lucida attached to a microscope. In order to draw an undistorted suture on a plane, several settings of the specimen must be made. For a curved surface of about 180 degrees, or half way around a shell, the writer made six or seven settings. After a part of a suture is copied, the fossil is turned so as to have the next portion of the suture nearly perpendicular to the axis of the microscope. In order not to depart from a constant orientation of the shell one must revolve it around the same or nearly the same axis, and in order to make proper connection of two neighboring portions of a suture the comparatively undistorted edges of the drawings of the two must somewhat overlap each other. The smallest magnification of ordinary microscopes used in paleontological laboratories with attached camera-lucida is about 10 times and, therefore, the drawn suture is usually too large and must be reduced. This can be done by photography or by a pantograph.

All of the sutures of *Baculites* shown on the accompanying plates were drawn by the direct method of tracing on cellophane, except Plate XXXV, figures 5d, 5e, which were drawn with the help of camera-lucida and subsequently reduced by pantograph. All the sutures of the *Scaphites* group were drawn with the help of camera-lucida and reduced by photography.

DESCRIPTION OF THE SPECIES

CLASS CEPHALOPODA—SUBCLASS TETRABRANCHIATA

ORDER AMMONOIDEA—SUBORDER EXTRASIPHONATA

FAMILY LYTOCERATIDÆ

SUBFAMILY MACROSCAPHITINÆ

Genus BACULITES Lamarck

"Shell with minute, closely coiled initial stage but quickly becoming straight and assuming the form of a staff which, with increasing age, increases slowly in diameter. Cross section subtriangular, oval, or subcircular, though usually more or less compressed laterally. Living chamber large, aperture with long, straight, rounded extension on the siphonal side and lateral sinuses. Surface smooth or with low rounded ribs that are parallel to the aperture and as a rule are distinct only on the flanks, or with low rounded nodes on the flanks. Suture has generally six saddles and six lobes; saddles bifid; lobes, except the antisiphonal lobe, bifid."[1]

Genotype. Baculites vertebralis Lamarck (Syst. des anim., p. 103).

The remains of *Baculites*, chiefly in the form of internal molds, are perhaps the most abundant fossils of the Pierre shale in Wallace county and elsewhere. The common smooth specimens from this formation are ordinarily referred to *Baculites ovatus* Say and *B. compressus* Say, which were instituted on material from the Upper Cretaceous of New Jersey and Upper Missouri river, respectively. Unfortunately, a clear conception of these species was not given in the original descriptions, and considerable confusion as to which features are typical for each species was thus created. In addition, the type specimens of *B. compressus* are lost. For the clearing up of the question as to which features must be considered typical for each of the two species, we owe much to F. B. Meek and J. B. Reeside, Jr. The latter author has pointed out that *B. compressus* of some authors (Morton, Whitfield) is not the *B. compressus* of Meek, but is a slightly compressed variety of *B. ovatus*. He furthermore has suggested acceptance of Meek's clear conception of *B. compressus,* based on topotypes of the species. Reeside proposes to separate the forms which have a suture closely resembling that of *B. ovatus,* but which have a somewhat compressed cross section resembling that of *B. compressus,* as *Baculites ovatus* var. *haresi* Reeside.

The writer collected chiefly from the middle and lower part of

1. After Reeside, 1927, p. 9.

the Pierre and from the topmost beds of this formation and found a considerable variety of forms closely related to *B. compressus* and *B. ovatus*. Among these are several specimens with the ovate cross section of the *B. ovatus* type, but with the suture, though not quite identical, nevertheless decidedly of the *B. compressus* type. He considers it preferable to give this form the new specific name *B. pseudovatus,* a new variety of which (*B. pseudovatus* var. A) is also provisionally recognized by him. The writer found numerous specimens which are identical with *B. compressus,* as described by Reeside,[2] in every respect, including the pronounced and regular corrugation of the siphonal edge. At the same time the writer collected from somewhat different horizons of the Pierre a few specimens indistinguishable from *B. compressus* as described by Meek and having only a slightly corrugated siphonal edge. He noticed, furthermore, that the sutures of the *B. compressus* Meek are more digitate than those of *B. compressus* Reeside. He distinguishes the form described by Reeside as *B. compressus* var. *reesidei* and recognizes in his material from Wallace county another variety with still more prominent corrugation of the siphonal side, which he designates as *B. compressus* var. *corrugatus.* This form has also some definite pecularities of the suture and its vertical range is much restricted.

The writer is aware that one may question the differentiation of so many species and varieties among forms which until recently were referred to only two species: *B. compressus* and *B. ovatus.* To this the writer answers that, besides the observed differences in form and suture, the definite stratigraphic position of these forms in the local Pierre section (as shown on the table, p. 297) justifies their record under separate names. It is possible that some of these varieties are mere responses of the species to local changes in the environments of the Pierre sea; but, at any rate, these forms appear to be of local stratigraphic value as horizon markers. On the other hand, some of the forms may prove to have wide stratigraphic importance and may help considerably in the distant correlation of subdivisions of the Pierre and contemporaneous formations, not only in North America but in the Upper Cretaceous formations elsewhere. It is significant that one species of *Baculites* from the Beecher Island shale, comparable in size, cross section, smoothness of the shell and characters of the suture to the *B. ovatus*[3] and *B. compressus* in the broadest sense, was found to be still more similar

2. Reeside, 1927, pp. 10-12.

3. In fact a specimen of this form in the old collection in the Kansas University was identified as *B. ovatus* Say, and another as *B. anceps* Lamarck.

and possibly identical with a specimen of *B. anceps* var. *Leopoliensis* described by Novak from the Upper Cretaceous of Poland. The writer feels that unless the forms commonly referred to *B. ovatus* and *B. compressus* are studied in more detail and are separated into species, subspecies and varieties, in somewhat the same way as has been done by Reeside for the *Baculites* of the Eagle Sandstone and related formations,[4] these widely distributed and important fossils will be of very little help as horizon markers, but will be merely characteristic of the whole Pierre. Furthermore, unless the various intermediate forms are recognized, the types themselves can be hardly treated as distinct species on account of the proven existence of a number of intermediate forms of all kinds; for instance, forms with compressed cross section and moderately digitate suture of the *B. ovatus* type and forms with ovate cross section and intensely digitate suture of the *B. compressus* type. The following is a key for identification of the *Baculites* of the Pierre and related formations.

For convenience of reference in the description of the species of *Baculites* a diagrammatic sketch of a typical suture of the genus is appended (Pl. XL, fig. 7). The suture consists of siphonal or ventral lobe (SL), first (lateral) saddle (1S), first lobe (1L), second saddle (2S), second lobe (2L), third (always small) saddle (3S), and antisiphonal or dorsal lobe (AL). The ventral lobe is very complex and consists of two lateral tripartite branches which are widely separated by a central broad saddle. As a result of his study of material from Wallace county, with the addition of the material illustrated in the literature, the writer concludes that the form and character of incision of this central part of the ventral lobe is of diagnostic value for the species and varieties of the *B. ovatus* and *B. compressus* group. Inasmuch as the terminology for the details of this part of the suture of *Baculites* is not worked out, he proposes the following terms, to which he attaches no biological or orthogenetic significance, but which are introduced for descriptive purposes alone. The whole broad, central portion of the ventral lobe between the two lateral branches is designated as the ventral or siphonal saddle (a term used already by some authors). This saddle is always distinctly subdivided into two smaller lateral saddles and a median saddle (*b*) between. The lateral saddles and median saddle are separated by what Meek described as "smaller digitate lateral branches" of the siphonal lobe. The comparative width of the *siphonal saddle*, the relative width and height of its central branch (*b*) and the character of incision of the latter (uni, bi-, tri-

4. Reeside, 1927.

KEY FOR THE IDENTIFICATION OF THE BACULITES OF THE PIERRE AND RELATED FORMATIONS

Species of Baculites.	Size, form and sculpture.					Character of Sutures.				
	Size (long dia. in millimeters).	Cross section.	Tapering (increase of long dia. per length of shell in millimeters).	Sculpture. Of flanks.	Sculpture. Of siphonal side.	Degree of dissection of lobes.	Stemlike body *a* supporting terminal branches of first lateral lobe. (See pl. xl, fig. 7).	Symmetry and orientation of second lateral lobe.	Middle branch *b* of siphonal sinus (see pl. XL, Fig. 7). Height in relation to lateral branches.	Middle branch *b* of siphonal sinus (see pl. XL, Fig. 7). Dissection.
B. ovatus Say	Moderate, to 50 mm. (possibly larger).	Elliptical to ovate.	Gradual, 1 to 2 per 50.	Smooth to obscurely undulated.	Smooth to gently wrinkled.	Slightly digitate.	None.	Symmetrical, erect.	Even.	Unipartite or bipartite.
B. ovatus var. *haresi* Reeside	Small, to 30 mm.	Oblong to ovate.	Gradual, 1 to 3 per 50.	Smooth to obscurely undulated.	Smooth or gently wrinkled.	Somewhat more dissected than in *B. ovatus*.	None.	Symmetrical, slightly inclined.	Lower.	Tripartite.
B. pseudovatus Elias, n. sp.	Moderate to large, to 75 mm.	Elliptical.	Gradual, 1 to 2 per 50.	Smooth.	Smooth or gently wrinkled.	Moderately dissected.	Long.	Antisiphonal side reduced, erect.	Much lower.	Bipartite.
B. pseudovatus var. A, Elias, n. var.	Moderate, to 40 mm.	Elliptical to ovate.	Gradual, 1 to 2 per 50.	Smooth.	Smooth.	Moderately dissected.	Short.	Nearly symmetrical, nearly erect.	Much lower.	Unipartite with tendency to tripartite.
B. compressus Say em. Meek	Moderate to large, to 50 mm. (possibly to 75 mm.).	Oblong-ovate, subtrigonal in later stages (Meek).	Moderate to rapid (particularly in the young—Meek) 2 to 5 per 50.	Smooth, extra large shells broadly undulated (Meek).	Smooth or gently wrinkled (3 to 4 wrinkles per 10 mm.	Much dissected.	Long.	Symmetrical, erect.	Lower.	Bipartite.
B. compressus var. *reesidei* Elias, n. var.	Moderate to 50 mm.	Elongately pyriform.	Moderate to rapid, 3 to 5 per 50.	Smooth.	Wrinkled, 2 wrinkles per 10 mm.	Moderately dissected.	Long.	Antisiphonal side reduced, erect.	Lower.	Tripartite.
B. compressus var. *corrugatus* Elias, n. var.	Moderate to large, to 70 mm.	Oblong to sublinear	Moderate, 2 per 50.	Smooth.	Prominently corrugated, 1 wrinkle per 10 mm.	Moderately to much dissected.	Long.	Symmetrical, inclined.	Slightly lower.	Tri- to five-partite.
B. clinolobatus Elias, n. sp.	Moderate, to 50 mm.	Oblong to elliptical.	Moderate to rapid, 3 to 4 per 50.	Smooth.	Smooth.	Moderately dissected.	None.	Symmetrical, inclined.	Lower.	Unipartite.
B. grandis Hall and Meek	Large to very large, to 100 mm.	Ovate to subcordiform.	Gradual, 1 per 50.	Broadly undulated, smooth in early stages	Smooth.	Slightly dissected.	None.	Erect, nearly symmetrical.	Lower.	Unipartite to irregularly digitate.
B. asper Morton	Small, to 30 mm.	Elliptical.	Gradual, 1 per 50.	Round nodes near antisiphonal side.	Numerous gentle wrinkles.	Moderately dissected.	None.	Nearly symmetrical, erect.	Even or slightly lower.	Unipartite.
B. meeki Elias, n. sp.	Small, to 30 mm.	Elliptical.	Moderate 3 per 50.	Oblique ridges.	Smooth.	Septa unknown.				

or quinquepartite) seem to be of diagnostic importance, while the shape and digitation of the lateral tripartite branches of the siphonal lobe, between which the siphonal saddle is developed, have been found fairly constant in the species of *Baculites* here described and were not found of use for specific distinction of the species and varieties studied by the writer.

Among the other features of the suture the presence or absence of a stem-like body (*a*) supporting the two parallel, slender and digitate terminal branches of the first lateral lobe has been considered a very important distinguishing character between *B. compressus* and *B. ovatus* by Meek and Reeside, which is wholly shared by the writer.

Another feature of the suture, which is used for specific distinction by the writer, is the shape of the second lateral lobe and its orientation in relation to the rest of the lobes and saddles which are always fairly parallel to each other. The second lobe in some species or varieties is distinctly inclined, with its apex toward the siphonal side. When not inclined the second lobe is symmetrical in some species while in others it is much reduced on the antisiphonal side, as if crowded by the development of the antisiphonal saddle.

Baculites ovatus Say

(Plate XXXIII, figs. 3a, b, c)

1820. *Baculites ovata* Say, Am. Jour. Sci., 1 ser., vol. 2, p. 41.

1828. *B. ovata* Morton, Jour. Acad. Nat. Sci. Phila., 1 ser., vol. 6, p. 89, pl. 5, figs. 5, 6.

1830. *B. ovatus* Morton, Am. Jour. Sci., 1 ser., vol. 17, p. 280; vol. 18, p. 249, pl. 1, figs. 6-8.

1830. *B. ovatus* Morton, Acad. Nat. Sci. Phila. Jour., 1 ser., vol. 6, p. 196, pl. 8, figs. 6-8.

1834. *B. ovatus* Morton, Synopsis of organic remains of the Cretaceous group in U. S. A., p. 42, pl. 1, figs. 6-8.

1853. *B. ovatus* Marcou, Explanatory text to geologic map of United States and British provinces of North America, p. 46, pl. 7, fig. 5.

1856. *B. ovatus* Hall and Meek, Am. Acad. Arts and Sci., Mem., new ser., vol. 5, p. 399, pl. 5, figs. 1a-e; pl. 6, figs. 1-7.

1875. *B. ovatus* White, U. S. Geol. Survey, W. 100th Mer. Rept., vol. 4, p. 199, pl. 19, figs. 4a-5a-c (not figs. 4-b-c).

1876. *B. ovatus* Meek, U. S. Geol. Survey, Terr. Rept., vol. 9, p. 394, pl. 20, figs. 1a-b, 2a-d.

1889. *B. ovatus* Whiteaves, Contr. Can. Pal., vol. 1, p. 181.

1892. *B. ovatus* Whitfield, U. S. Geol. Survey, Mon. 18, p. 275, pl. 46, figs. 3-9.

1907. *B. ovatus* Weller, New Jersey Geol. Survey, Pal., vol. 4, p. 821, pl. 109, fig. 5.

1910. *B. ovatus* Grabau and Shimer, North American Index Fossils, p. 181, figs. 1437, 1438.

1916. *B. ovatus* Gardner, Maryland Geol. Survey, Upper Cretaceous, pp. 375-377, pl. 12, figs. 2, 3.

1917. *B. ovatus* Dowling, Can. Geol. Surv., Mem. 95, p. 31, figs. 2, 2a.

1926. *B. ovatus* Wade, U. S. Geol. Survey, Prof. Paper 137, p. 181, pl. 60, fig. 9.

1927. *B. ovatus* Reeside, U. S. Geol. Survey, Prof. Paper 151, p. 9, pl. 5, figs. 12, 13; pl. 6, figs. 1-4; pl. 7, figs. 1-8.

The species may be recognized by its ovate to elliptical cross section; smooth or, in the latest stages, obscurely undulated flanks; moderately large size; relatively simple, little incised suture. It differs from *B. compressus* Say in its ovate cross section and much less digitate suture.

This species, though widespread elsewhere, has not been found as yet in Kansas,[5] and only a few specimens of *B. ovatus* var. *haresi* Reeside were collected by the writer in Wallace county. According to Reeside *B. ovatus* is found in the Eagle and Telegraph Creek formations of Montana and Wyoming, in the lower half of the Pierre shale of the western Black Hills region and in equivalent formations of the midwestern states; also "in the later parts of the Montana group up to the base of the Fox Hills sandstone, and in the later Cretaceous formations of the Atlantic and Gulf Coastal Plain."[6] Meek believed that the species "ranges all through the Fort Pierre group, and up into the Fox Hills beds of the Upper Missouri Cretaceous series."[7]

The writer considers it quite possible that with separation of *B. ovatus* in the restricted sense from the somewhat similar *B. pseudovatus* and *B. clinolobatus*, the stratigraphic distribution of *B. ovatus* will be reduced and will possibly be limited to the lowermost portion of the Pierre, to the Telegraph Creek and Eagle formations and to their equivalents. The specimens of undoubted *B. ovatus*, illustrated by Reeside, came from 1,400 feet below the top of the Steele shale of Wyoming (pl. V, figs. 12, 13) and from the Eagle sandstone of Montana (pl. VII, figs. 3-5).[8]

Baculites ovatus var. *haresi* Reeside

(Plate XXXV, figs. 3a, b, 4a, b)

1927. *Baculites ovatus* Say var. *haresi* Reeside. U. S. Geol. Survey, Prof. Paper 151, p. 10, pl. 6, figs. 5-10; pl. 7, figs. 9, 10.

According to Reeside the shell is smooth with dorsum and venter rounded, and it has a relatively simple suture of the *B. ovatus* type. It differs from *B. ovatus* in possessing a compressed shell. In cross section it differs from *B. compressus* "in lacking the tendency to taper toward the siphonal side and in the details of the suture"

5. *B. ovatus* was recorded in the Pierre of Kansas by Logan (1897, pp. 222, 230-231, and 1898, p. 509), but inasmuch as this record was made at a time when the clear conception of the characteristics of the species was not established, and since no description or figures of the Kansas form is given, the validity of the record may be questioned. There are no specimens of *B. ovatus* in the old collections from western Kansas at the University.

6. Reeside, 1927, p. 10.

7. Meek, 1876, p. 397.

8. Both illustrated by Reeside, 1927.

(Reeside, 1927, p. 10). The specimens from Wallace county, which are here referred to the variety *haresi*, have the shell smooth on all sides and with a cross section of the *haresi* type (Pl. XXXV, fig. 4b). The suture of Kansas specimens has slightly more dissected lateral sinuses, but the lobes are designed in much the same fashion as in *haresi* from Wyoming (Pl. XXXV, fig. 3a). Though the dissected sinuses of Kansas specimens somewhat resemble the corresponding parts of the *compressus* type of suture, the terminal of the first lateral lobe is decidedly unlike that in *B. compressus*, but like that in *B. ovatus* and its variety *haresi*. The second lateral lobe is somewhat inclined in both the Wyoming and Kansas specimens.

Occurrence. Upper part of the Upper Weskan shale member and base of the Lake Creek shale member in sec. 15, T. 12 S., R. 38 W., Wallace county, Kansas.

According to Reeside, in the Telegraph Creek and Eagle sandstone formations of Montana and Wyoming; in the lower part of the Pierre shale on the western and northern rim of the Black Hills; in the Steele shale of Wyoming and the upper part of the Mancos shale in Utah and New Mexico.[9]

Baculites compressus Say

1820. ***Baculites compressa*** **Say, Am. Jour. Sci., 1 ser., vol. 2, pp. 41, 42.**

Not 1833. ***Baculites compressa*** **Morton, Am. Jour. Sci., 1 ser., vol. 23, p. 291; vol. 24, pl. 9, fig. 1.**

Not 1834. ***Baculites compressus*** **Morton, Synopsis of the organic remains of the Cretaceous group in the United States, p. 43, pl. 9, fig. 1.**

Not 1892. ***Baculites compressus*** **Whitfield, U. S. Geol. Survey, Mon. 18, p. 277, pl. 46, figs. 1, 2.**

For revision of the conception of the *compressus* species we are indebted to J. B. Reeside, Jr., whose opinion that Morton and Whitfield described under the name *compressus* a variety of *B. ovatus* is wholly shared by the writer. Since the type specimen, which was inadequately described and never figured by Say, is apparently lost, it is logical to accept Meek's clear characterization of the species, as suggested by Reeside, because the material which Meek collected and described came in part "from the region where Say's specimen was obtained." Morton's specimen, which was erroneously supposed to be the type of Say's species, and which was redescribed and refigured by Whitfield, has septa much like those of *B. ovatus* and can be justly classified with *B. ovatus* var. *haresi* Reeside, as proposed by Reeside. For a complete discussion of *B. compressus* of earlier authors see Reeside, 1927 (pp. 10, 11).

9. Reeside, 1927, p. 10.

Though the writer agrees that the specimen described and figured by Reeside and referred to *B. compressus* is similar in cross section and characters of the sutures with *B. compressus* as illustrated and described by Meek, there are some differences between Meek's and Reeside's specimens which may justify the separation of the latter as a variety of *B. compressus* Meek. This conclusion was reached by the writer after comparative study of numerous specimens of *B. compressus* from Wallace county, among which both the specimens comparable to Meek's and to Reeside's forms were recognized. The two forms were found in somewhat different horizons of the Pierre and thus proved to be of at least local stratigraphic value. The writer proposes to consider the form described by Meek as *Baculites compressus* s. s., and the form described by Reeside as the type of *B. compressus* var. *reesidei.*

Baculites compressus Say, Meek, s. s.

(Plate XXVIII, fig. 4; Plate XXXII, figs. 3a, b, 4a, b, c, 5a, b)

1854. *Baculites compressus* Hall and Meek, Am. Acad. Arts and Sci., Mem., new ser., vol. 5, pp. 400-402, pl. 5, figs. 2a, b; pl. 6, figs. 8, 9.

1876. *Baculites compressus* Meek, U. S. Geol. Survey, Terr. Rept., vol. 9, pp. 400-404, pl. 20, figs. 30a-c; text figs. 55, 56.

"Shell attaining a large size, rather rapidly tapering, particularly in the young, or near the smaller extremity of adult specimens, strongly compressed laterally in medium-sized examples, but more convex in the young and toward the larger extremity of large adults; nonseptate portion of fully developed specimens provided with large broad lateral undulations; lines of growth generally obscure; siphonal margin sometimes crossed by small undefined wrinkles; transverse section, like the outline of the aperture, varying with size and age, being ovate in very small specimens, strongly compressed in medium sized examples and proportionately more broadly ovate in the large adult.

"Septa usually crowded, and with lobes and sinuses deeply divided into slender branches; siphonal lobe nearly twice as wide as long and provided with two widely separated tripartite and digitate terminal branches and one smaller digitate lateral branch on each side; first lateral sinus as long as the siphonal lobe, but not much more than half as wide and very deeply divided at the end into two equal tripartite and digitate branches, with spreading subdivisions; first lateral lobe longer than the siphonal lobe, and about half as wide, with two small, parallel, sharply digitate terminal branches, standing, as it were, on a stem formed by the very narrow body which also supports on each side two opposite, sharply digitate lateral branches, one pair of which shows more or less tendency to tripart division; second lateral sinus usually a little longer, but otherwise very similar to the first; second lateral lobe shorter and broader than the first, and provided with two equal tripartite and digitate, spreading terminal branches, with much smaller, irregular, lateral branchlets; third lateral sinus usually not larger than one of the main terminal branches of the others, and deeply bifurcated at the end, the divisions

being more or less subdivided, or merely digitate; antisiphonal lobe generally only about half as long as the second lateral, and much narrower, with two to four very small lateral branches, or mere digitations on each side, and one small, tridentate, terminal division."[10]

In his material from Wallace county the writer has observed some specimens which are identical in every respect with the specimens of *B. compressus* as illustrated and described by Meek, and which, in some minor respects, differ from the more numerous specimens which he proposes to separate under the name *B. compressus* var. *reesidei*. The suture of *B. compressus* in a strict sense differs from the suture of *reesidei* in the following way:

1. The median saddle of the siphonal saddle is divided into two slightly dentate saddles *b-b* by a very short but sharp wedge-like siphonal lobe, while the corresponding small median saddle of B. *compressus* var. *reesidei* is tripartite.

2. The second lobe of *B. compressus* s. s. is wider than the second saddle and about as symmetrical as the latter, while the second lobe of var. *reesidei* is always asymmetrical with reduced branches on the antisiphonal side.

The specimens (Pl. XXVIII, fig. 4, and Pl. XXXII, figs. 4a, 4b, 4c, 5a, 5b) of the collection from Wallace county can be referred to *B. compressus* without much doubt. Their sutures are decidedly of the *B. compressus* s. s. type, being deeply digitate and having broad and symmetrical second lobes. The small median saddle (*b*) of the siphonal lobe is bipartite. The cross section of the younger of the Wallace county specimens (Pl. XXXII, fig. 4c) is about the same size and is as much compressed as Meek's type (Pl. XXXII, fig. 3b), though there is a slight, but hardly important, difference in the shape of the cross sections, the widest part of the Wallace county specimen being about in the middle of the cross section. The specimen has a very gentle but distinct and regular plication of the siphonal edge, a feature in agreement with Meek's note that the siphonal margin is "sometimes crossed by small undefined wrinkles." The regular plication of the siphonal edge of our specimens is certainly very gentle and wrinkles are quite small, the distance from one depression to another being 2 to 3 mm.

The largest Wallace county specimen is a fragment incomplete on the siphonal side (Pl. XXXII, fig. 5b). The antisiphonal side of this specimen is abruptly rounded, much like the cross section of the medium-sized *B. compressus*, as shown in text figure 55 on page 403 of Meek's monograph (Meek, 1876). Meek observed strong

10. Meek, 1876, pp. 400, 401.

lateral undulations on the nonseptate part of a large specimen of *B. compressus* (Meek, 1876, text figure 56, p. 403), but the nonseptate portion of large *B. compressus* s. s. was not collected in the Pierre of Wallace county.

Occurrence. Upper part of the Upper Weskan shale, and through the Lake Creek shale member except the top of it where the form becomes scarce or is, possibly, absent. According to Meek, in the Pierre exposed at the Great Bend of Missouri river below Fort Pierre and from "higher positions in the same formation" on Sage creek, at the Bad Lands and on Cheyenne river of South Dakota (Meek, 1876, p. 403).

The specimens described by Meek were collected in the Upper Missouri exposures of the Pierre formation, where also the type of Say was found.

Baculites compressus var. *reesidei* Elias, n. var.

(Plate XXVIII, fig. 1; Plate XXXI, fig. 3; Plate XXXII, figs. 2a, b, c; Plate XXXIII, figs. 1a, b. c; 2a, b, c)

1927. ***Baculites compressus*** **Reeside, U. S. Geol. Survey, Prof. Paper 151, pp. 10-12, pl. 9, figs. 1-5.**

The specimen described and figured by Reeside has the typical compressed form of *B. compressus* and a much digitate suture with the characteristic detail of the *compressus* type: "Two small, parallel, sharply digitate, terminal branches" of the first lateral lobe "standing, as it were, on a stem formed by the very narrow body."

The differences between the suture of var. *reesidei* and that of *B. compressus* s. s. are as follows:

1. The suture of *reesidei* is all in all comparatively less digitate.
2. The second lateral lobe of *reesidei* is comparatively narrower than the corresponding lobe of *compressus* s. s., and besides is distinctly asymmetrical, being crowded by the third lateral saddle, which is less digitate on the side facing the second lobe than in *compressus* s. s.
3. The two large tripartite terminal branches of the second lateral saddle are standing on a narrow base in typical *B. compressus,* while in var. *reesidei* the supporting base is several times wider.
4. The small median saddle (*b*) of *reesidei* is subdivided into three rounded branches, while the corresponding portion of the siphonal saddle of *compressus* s. s. is bipartite.

Besides the difference in suture the var. *reesidei* is differently ornamented on the siphonal edge than *B. compressus* s. s. The edge of the type, as figured by Reeside, is pronouncedly and regularly plicated, the distance between plications being 4 to 5 mm., or about 2 times larger than between the far less pronounced and smaller wrinkles of *B. compressus* s. s. of Wallace county. The plications of the siphonal edge of specimens of var. *reesidei* collected by the writer have a distance between plications of 4 to 5 mm. on the moderate-sized types.

Occurrence. Lake Creek shale member and lower part of Salt Grass shale member of the Pierre shale, Wallace county, Kansas. The specimen illustrated by Reeside (1927, Pl. 9, figs. 1-5) and reproduced here (Pl. XXXII, fig. 2) came from the Eagle sandstone of Montana, where the form is, however, so rare that Reeside raises a question "whether these specimens really came from the zone containing the Eagle fauna, and it must be left for future experience to determine whether *B. compressus* actually does belong to the Eagle fauna or is restricted to later faunas." [11]

Baculites compressus var. *corrugatus* Elias, n. var.

(Plate XXVIII, fig. 3; Plate XXX, fig. 3; Plate XXXII, figs. 1a, b, c)

Many compressed specimens of *B. compressus* with a still more pronouncedly corrugated siphonal side than in var. *reesidei* have been collected in the upper portion of Lake Creek shale member. The pronounced wrinkles of the siphonal side are about 10 mm. apart. The typical cross section of this variety is shown on Plate XXXII, figure 1c. The suture is decidedly of the *B. compressus* type, being deeply dissected and having terminal branches of the first lateral lobe standing on the slender stem-like body (*a*). However, the suture of this variety differs from that of *B. compressus* s. s. and of var. *reesidei* in having an inclined second lateral lobe. Furthermore the small median saddle (*b*) is tripartite with a further splitting of its lateral branchlets into two. The variety *corrugatus* differs from both typical *B. compressus* and var. *reesidei* in having a very gradually tapering shell. The type of the var. *corrugatus* (Pl. XXVIII, fig. 3) was collected and presented to the writer by Mr. Joe De Tilla, of Wallace.

A long and slender specimen of *Baculites* with cross section and suture of the *compressus* (in broad sense) type was collected in an

11. Reeside, 1927, p. 12. Reeside is now convinced that the species "does not range so low" and that *B. compressus* is wholly upper Pierre form (personal notes to the writer, April, 1931).

irregular body of "Lucina limestone" at the base of the Salt Grass shale member. This specimen allows study of the change of suture with growth of the shell. Though the initial coiled portion of the shell is not preserved, a straight portion about 48 cm. long and 5 to 31 mm. wide (in the long diameter) was secured. Several stages of the suture of this specimen are shown on Plate XXXV, figures 5b, 5c, 5d, 5e. The comparison of these sutures with those of *B. compressus* s. s. and *B. compressus* var. *reesidei* and *corrugatus* shows that in this case the former or more incised (*compressus* s. s.) type of suture is ancestral to the less incised *reesidei* and *corrugatus* types.

It is interesting to recall that in the earliest stages of the straightened shell of *B. compressus,* as demonstrated by Brown (1891, p. 159), the suture develops gradually from a slightly wavy line to the complicatedly curved and dissected sutures of the later stages. This is also a generally observed fact for all Ammonoidea, which ordinarily show a gradual complication and increased dissection of the suture with the growth of the shell. Therefore, the subsequent change from a more complicated suture to a less digitate type, as now demonstrated for this variety of *B. compressus,* is an interesting case of simplification of suture within the last survivals of the genus *Baculites* of the North American Cretaceous sea. Compare, also, the return to a less dissected type of suture with the growth of the shell in *B. grandis* (p. 347 of this paper, Pl. XXXIV, figs. 4 and 5a, b).

The evidence of a later appearance of the *reesidei* type of suture as compared with the typical *B. compressus* suture, agrees with field evidence gathered in Wallace county that *reesidei* and *corrugatus* appear in somewhat higher horizons of the Pierre formation than typical *B. compressus* s. s.

Occurrence. Var. *corrugatus* is perhaps the most common *Baculites* in the upper part of the Lake Creek shale member of the Pierre shale, while it was not found in the lower half of the member or higher than at the base of the Salt Grass shale member in Wallace county.

Baculites pseudovatus Elias, n. sp.

(Plate XXIX, figs. 1a, 1b, 2; Plate XXXIII, figs. 4a, b)

Among the specimens of *Baculites* collected from the Pierre of Wallace county there are some which have a smooth ventral side and a cross section of the *B. ovatus* type, but the suture is decidedly not that of *ovatus,* being about as much dissected as the suture of *compressus.* The writer proposes to separate these forms under a new specific name, *pseudovatus.* The forms of *Baculites* which have

sutures of the *ovatus* type but a cross section approaching that of *compressus* have been separated already by Reeside and named *B. ovatus* var. *haresi*.[12] This author states that: "An examination of a large number of specimens from various horizons, preserved in the collections in the United States National Museum, showed but one specimen combining the evenly rounded form of *B. ovatus* and the suture of *B. compressus*."[13] It would be interesting to compare the suture line of this specimen with that of *B. pseudovatus* from Wallace county, where this species and its varieties are fairly common.

Description of the *pseudovatus* suture line is as follows: Sutures moderately closely spaced; lobes and saddles not as deeply subdivided as in *B. compressus* s. s., but deeper than in *B. compressus* var. *reesidei;* siphonal saddle very narrow, being only one and a half times as wide as long, while in the latter two forms it is nearly two times as wide as long. The tripartite lateral branches of the siphonal lobe are cut in nearly the same way as in *reesidei,* while the siphonal saddle is different from both *compressus* s. s. and *reesidei,* being as wide as long, or two times narrower than in the latter two; the middle incisions of the first and second saddles are sharply pointed down at the terminal, while in the latter two the corresponding incisions finger out at the terminals; the first lateral lobe is almost perfectly round in the outline, while the corresponding lobe of *B. compressus* s. s. and var. *reesidei* is ovate or egg-shaped with the sharp end pointing distad; the two terminal branches of this lobe, which in *B. compressus* are "standing, as it were, on a stem formed by the very narrow body" (*a*), are not "parallel and sharply digitate" as in *B. compressus* s. s. and var. *reesidei,* but bifurcate each. The third saddle and the antisiphonal lobe are the same as in *B. compressus* in a broad sense.

The type specimen of this form, showing distinct sutures, was found in the limestone concretions of the middle zone of the Upper Weskan shale member. It is of moderately large size, having a long diameter of 66 mm. and a short diameter 44 mm. at the end of the septate part of the internal cast.

Numerous individuals of smaller size, not exceeding 40 mm. in the long diameter of the oval, or only slightly compressed cross section and quite smooth on the outside, are very common in the middle part of the Salt Grass shale member. Unfortunately the sutures of these numerous molds, when preserved at all, are so much

12. Reeside, 1927, p. 10.
13. Ibid., p. 11.

weathered as to preclude any reliable comparison. However, in a very few cases the suture was sufficiently preserved to allow the writer to see that it is decidedly not of the *ovatus* type, but is much closer to that of *B. pseudovatus.* The nearly complete suture of the best specimen is illustrated (Pl. XXXIII, figs. 5a, b). Some differences between this suture and that of the typical *B. pseudovatus* (Pl. XXXIII, fig. 4a) can be noticed which may justify the separation of the smaller shell as a distinct variety of *B. pseudovatus.* This separation has support in the fact that the smaller shell was found stratigraphically higher than the typical *B. pseudovatus.* The smaller form is provisionally designated here as *B. pseudovatus* var. *A* (Pl. XXVIII, fig. 2, and Pl. XXXIII, figs. 5a, 5b).

Occurrence. The type specimen of *B. pseudovatus* was found in the limestone concretion bed (No. 8) of the Upper Weskan shale member. The few specimens with ovate cross section but without any suture line which were collected near the lower part of Lake Creek shale member most probably belong to this species. The form designated here as *B. pseudovatus* var. *A* is very common in the middle zone of the Salt Grass shale member, where other fossils are rare.

Intermediate forms. There are a few specimens from the Pierre of Wallace county which may be considered intermediate forms between *B. pseudovatus* and *B. compressus* var. *reesidei.* The specimen of which the suture and cross section are shown on Plate XXXI, fig. 3, and Plate XXXIII, figs. 1a, 1b, is close to *B. compressus* var. *reesidei,* but is not as compressed as the latter and has only very faint wrinkles on the siphonal side. This specimen came from the lower half of Lake Creek shale member.

The specimens of Plate XXXV, figs. 1a, 1b and 2a, 2b, resemble *B. pseudovatus* var. A, but are comparatively more compressed. The shell of both is perfectly smooth with only very faint wrinkles on the siphonal side. The suture is of intermediate type between var. A and *B. compressus* var. *reesidei.* The specimen of Plate XXXV, figs. 1a, 1b, came from the middle zone of the Salt Grass shale member, and the specimen of Plate XXXI, figs. 2a, 2b, came from the basal zone of the same member.

Baculites grandis Hall and Meek

(Plate XXXI, figs. 1a, 1b, 2a, 2b; Plate XXXIV, figs. 4, 5a, 5b, 5c)

1854. *Baculites grandis* Hall and Meek, Am. Acad. Arts & Sci., Mem., new ser., vol. 5, p. 402, pl. 7, figs. 1, 2; pl. 8, figs. 1, 2; pl. 6, fig. 10.

1876. *B. grandis* Meek, U. S. Geol. Surv. Terr., vol. 9, p. 398, pl. 33, figs. 1a-b-c.

1926. *B. grandis* Wade, U. S. Geol. Survey, Prof. Paper 137, p. 182, pl. 60, figs. 8 and 12.

This species is recognized chiefly by the outstanding large diameter of the shell (long diameter as much as 4 inches) and very broad and strongly elevated undulations (Hall and Meek, 1854). The suture of this species closely resembles that of *B. ovatus.* Hall and Meek describe the type specimen of *B. grandis* as follows:[14]

"Shell elongate; section varying from ovate to subcordiform; surface of cast marked by very broad and strongly elevated undulations, which commence at the dorsum and pass obliquely downward, increasing rapidly in size and, crossing the sides of the shell in a broad curve, terminate abruptly on the ventro-lateral region. Undulations less distinct toward the smaller extremity and finally become obsolete. Septa very deeply lobed, principal divisions scarcely divergent. Dorsal lobe three-fourths as long and twice as wide as the superior lateral lobe; terminated on each side by a narrow elongated branch, which is irregularly sinuate and digitate at the extremity. Dorsal saddle shorter and wider than the superior lateral lobe, formed by four branches, the two terminal ones much the larger and each of them bifid at the extremity by a small sinus; the whole outline more or less sinuous and the extremities digitate. Superior lateral lobe longer by one-fifth than the inferior lateral lobe, narrower than the ventral saddle, divided at its extremity by a deep sinus into two equal parts, which are simply digitate; above these are two unequal branches on each side; terminal sinus much deeper than the lateral ones. Ventral saddle longer and about as wide as the dorsal saddle, more deeply divided at its extremity by the auxiliary lobe into two, nearly equal, branches, each of which is bifid and the extremities digitate, ventral side with three and dorsal side with two auxiliary branches. Inferior lateral lobe shorter and broader than the superior lateral lobe, divided at its extremity into two, nearly equal, branches, the one on the dorsal side bifid at the tip and the other digitate, with an auxiliary branch on the ventral side. Ventral lobe as long as the auxiliary lobe of the ventral saddle, but wider at the base, digitate at its extremity.

"Angle of the apex about 5°. Length, as deduced from the measurement of fragments, by the convergence of the dorsal and ventral sides, 5½ feet or more. Longest diameter of a fragment not distorted by pressure, 3.7 inches; shorter diameter from the surface of undulations, 3.3 inches; in the depressions between the undulations, 2.95 inches.

"The species is nearly related to *B. ovatus* of Say, from which it differs in its much greater size, larger apical angle, much stronger and more extended undulations, which cross the entire lateral surface of the shell. The section is more obtusely ovate; the lobes of the septa are much deeper, narrower, and less divergent in their branches; the digitations are sharper and more directly pointed in the longitudinal direction of the shell. The auxiliary lobe of the

14. Hall and Meek, 1854, p. 402.

ventral saddle is longer in this species, while the extremities of the terminal branches are less deeply bifid than in *B. ovatus*. In this species the two terminal branches of the superior lateral lobe are simply digitate, while in *B. ovatus* they are deeply bifid, with obtuse sinuosities. Externally in its undulations on the sides, this species resembles *B. anceps* of Lamarck, but will be readily distinguished by the absence of a dorsal carina and by its much deeper lobes with less divergent divisions. A comparison of the details of the divisions of the lobes and saddles shows a constant difference in the two species."

No specimens of this species were collected in Wallace county, the Pierre shale of which represents horizons of the formation below those in which this species has been found elsewhere. However, the writer collected from the Pierre shale of Beecher Island, Colorado, some perfectly preserved internal molds of *B. grandis*, the longer diameter of which varied from 2 to 3¾ inches. The molds show strong lateral undulations of the *B. grandis* type, and they have the sutures figured on Plate XXXIV, fig. 4, of this report.

A long specimen of *B. grandis* showing the younger stages of the shell (but not the very earliest stages and the initial coil) was collected in the Pierre at the NW¼, sec. 2, T. 2 S., R. 40 W., Cheyenne county, Kansas. The changes in the cross section of the shell and in the suture line of this specimen are illustrated on Plate XXXIV, figs. 5a, 5b, 5c. The most evident and important changes are the following:

(1) The pronounced lateral undulations, which are so typical for the adult shell, do not exist at all in the younger stages, where the sides of the shell are perfectly smooth.

(2) Contrary to the above mentioned change, the siphonal side of the shell is smooth in the adults, but in the young stages there appear occasional faint to moderately strong wrinkles spaced about 4 mm. apart.

(3) The first and second saddles are more incised in younger stages of the shell. While the degree of dissection of these saddles in the adult sutures of the shell can be (and always have been) compared with that of *B. ovatus*, the degree of dissection in younger stages is comparable to that in the adult shells of *B. compressus* var. *reesidei* and var. *corrugatus*.

(4) The central incision between the two terminal branches of the first lateral lobe is shorter in comparison with these branches in earlier stages, while the next two lateral incisions of the terminal have a tendency to come closer together and build the slender stem (*a*) supporting the terminal branches, which is a very characteristic feature of the *B. compressus* type of suture.

(5) In the younger stages the second lateral lobe is inclined as in *B. clinolobatus* and *B. compressus* var. *corrugatus.*

(6) In younger stages the cross section is elliptical and much compressed, while in the adult shell it is subtrigonal to oval.

All in all the earlier stages of the shell of *B. grandis* resemble in many respects the shell of *B. compressus,* and especially *B. compressus* var. *corrugatus. B. grandis* has been often compared with *B. ovatus* and inasmuch as it appears later in the Upper Cretaceous than the latter form, one is tempted to surmise that *ovatus* is an ancestral form to *grandis.* However, if the form and suture of the earlier stages of *B. grandis* are regarded as suggestive of the general appearance of the ancestral form, it must be a shell of the *B. compressus* type from which *B. grandis* descended.

Occurrence. Several localities at Black Wolf Creek, Beecher Island, Yuma county, Colorado, chiefly in and about large limestone concretions at the base of the Beecher Island shale. From the same zone in Hackberry creek and tributaries to Arikaree river in northwestern part of Cheyenne county, Kansas.

B. grandis is the most typical baculite of the topmost beds of the Pierre, but originally it was arbitrarily referred to Fox Hills formation by Meek.[15] Later, however, a belief was expressed that "neither *Baculites* nor *Inoceramus* is known to occur in the Fox Hills sandstone,"[16] and this is now generally accepted. Species of *Baculites* were recorded from the "Fox Hills" formation at Cooper Creek and at Point of Rocks of Laramie Plains, Wyoming,[17] at Bighorn Mountains[18] and in eastern Colorado.[19] According to Reeside none of these are in the Fox Hills, but rather in the Upper Pierre. In the Colorado foothills Fox Hills of the older literature is mostly Pierre.[20] Recently "some of the concretions" in the zone about 1,120 feet above the base of the "Fox Hills sandstone" of Fossil Creek were noticed to be "crowded with *Baculites*."[21] If the latter identification is correct, the survival of the genus *Baculites* high into what is usually considered by field geologists as Fox Hills formation must be considered proved unless the lithological criterion which is usually employed to distinguish Fox Hills sandstone from the Pierre shale

15. Meek, 1876, pp. 338-340.
16. Stanton, 1925, p. 8.
17. Stanton, 1897, p. 141 and p. 147.
18. Stanton in Darton, 1905, p. 52.
19. Darton, 1905, p. 1[illegible]
20. Personal note by Reeside, April, 1931.
21. Mather, Gilluly and Lusk, 1928, p. 96.

is not reliable at all and some other means of recognition of the Fox Hills sediments must be adopted.

The simultaneous disappearance in the Upper Cretaceous seas of North America of *Baculites* and *Inoceramus* can be arbitrarily chosen as the end of the Pierre time, but this feature alone is only a negative characteristic for Fox Hills time. According to Reeside,[22] the genus *Sphenodiscus* is restricted to the Fox Hills and is our best marker for the formation.

Baculites clinolobatus Elias, n. sp.

(Plate XXX, figs. 1, 2; Plate XXXIV, figs. 1, 2a, 2b, 3)

1908. *Baculites anceps* var. *leopoliensis* Novak, Bull. Acad. Sci., Cracovie, 1908, p. 326, text fig., p. 331, pl. 14, fig. 10.

Among the material collected from the Pierre shale at Beecher Island, Colorado, there are several perfectly preserved specimens with smooth surface, moderately compressed oval cross section, and a very interesting suture which is different from the rest of the American baculites known to the writer. The suture line is certainly more dissected than those of *B. ovatus* and *B. grandis* and is about as digitate as that of *B. compressus* var. *reesidei*. There are, however, some important differences which do not permit the classification of the Beecher Island species with the latter variety of *B. compressus* (or with the typical *B. compressus*). Besides the smoothness of the siphonal side of the shell and the only slightly compressed oval cross section, the design of the suture is considerably different. The siphonal lobe is as wide as long. The first lateral lobe is as oval in outline as that of *B. pseudovatus* var. A, but differs considerably from both *B. pseudovatus* and *B. compressus* by having the terminal branches not standing "on a stem formed by the very narrow body," as in all these species. They are here much separated by a prominent and long incision, which cuts the lobe deeply into two large bipartite terminal branchlets. The second lobe is not parallel to the rest of the lobes and saddles, but is considerably inclined to the axis of the shell. At the same time the inclined lobe is symmetrical in itself, having the branches of each side of equal size and sequence.

It is interesting to note that the suture of *B. clinolobatus* is more similar to one of the European types than to any one of the American species so far described. On Plate XXXIV, fig. 3, the suture line of *Baculites anceps* var. *leopoliensis* Novak is shown for comparison

22. Unpublished stratigraphic chart of Upper Cretaceous, 1930.

with the Beecher Island species. The striking similarity of the following features in the suture line of the American and European species may be noted: (1) General character and degree of dissection; (2) vertically elongated terminal branches of both the first and second lateral saddle; (3) perfectly oval outline of the first lateral lobes, which besides are dissected in the very same fashion; (4) inclination of the second lobes, the dissection of which is again very similar; (5) small, bipartite and not digitate median saddle (*b*) of the siphonal saddle.

Taking into account the character and the degree of variability of the sutures within the same individual, as exhibited in our specimen from Beecher Island (compare the two neighboring sutures of Plate XXXIV, figs. 1 and 2a), one comes to the conclusion that there is not the slightest difference between the sutures of the American and the European forms. If we add to this the similarities of the size, outline and smoothness of the septate portions of the shells, we have to confess that the two are as identical as two individuals of the same species can ever be expected to be, and therefore they should be classified under the same specific name. The writer, however, hesitates to apply to the American specimen the name *Baculites anceps* var. *leopoliensis*, because the other sutures of the same varieties, as shown on figures 5 to 9, page 331, of Novak's paper,[23] are quite different from that of figure 10, page 331, of the same paper, which is compared here with the suture of the Beecher Island form. These other sutures of the var. *leopoliensis* Novak are much like the sutures of *Baculites grandis* or *B. ovatus*, and one may question the identity of these with the specimen the suture of which is shown on figure 10, page 331, of Novak's paper, unless extreme variability of the septa of var. *leopoliensis* is admitted. The much confused situation in regard to the conception of the European species *anceps* has been pointed out by Meek, who judged "from published figures and descriptions . . . that shells belonging to more than one species have been included under Lamarck's name."[24] The situation concerning the limits of *anceps* has not improved appreciably since Meek's time, and recently again it has been pointed out that there is "a considerable variation in the concept of the species held by European students."[25]

It is advisable, therefore, to give the American forms, which are

23. Novak, 1908.
24. Meek, 1876, p. 407.
25. Reeside, 1927, p. 12.

related and in part apparently identical with some specimens referred to *B. anceps* by European authors, separate specific names, as was done in a similar case by Reeside.[26] At the same time the relation and even identity of the American forms with this or that particular European form described under the name *B. anceps* must be pointed out.

Distribution. Topmost Pierre or transitional to Fox Hills beds of shale exposed at Black Wolf Creek, near Beecher Island, Yuma county, Colorado. Also probably from the same zone of the Pierre in Cheyenne county, Kansas. The perfect molds of *Baculites* from this county in the old collection of the Geology Department of the University of Kansas are labeled *B. anceps.* They are indistinguishable from *B. clinolobatus* of Beecher Island.

Baculites meeki Elias, n. sp.

(Plate XXX, figs. 4a, 4b)

1876. *Baculites asper?* Meek, Rept. Invert. Cret. and Tert. Fossils, U. S. Geol. Survey, Terr., vol. 9, p. 404, pl. 39, figs. 10b, 10c (not figs. 10a, 10d).

Meek described two small fragments of internal molds which he doubtfully referred to *B. asper* and thought to have the same stratigraphic position "near the top of the Fox Hills group of the Upper Missouri Cretaceous series."[27] Recently Reeside, who described a much better *B. asper* from Montana and other midwestern states, correctly admitted to this species only that specimen of Meek which was illustrated on Plate 39, figures 10a, d.[28] That the two fragments belong probably to two different species was realized by Meek himself. Speaking of the fragment shown in figures 10b and c, he says, "I can scarcely doubt now that it represents a distinct species, its strong, oblique, nearly straight ridges or undulations extending entirely across the sides being a very marked feature, contrasting strongly with the nodelike prominence on the other specimen represented by figures 10a, d."[29] A fragment of the same size, cross section and sculpture (Pl. XXX, figs. 4a, 4b) was collected by the writer in the Pierre shale at Beecher Island. This checks to some extent the stratigraphic position of this rare and interesting form high in the section of the Upper Cretaceous and makes it worthy of designation by a separate name.

26. Ibid., p. 12, *Baculites aquilænsis* and its varieties.
27. Meek, 1876, p. 405.
28. Reeside, 1927, p. 13.
29. Meek, 1876, p. 405.

The names *asperoides* or *asperiformis*, proposed by Meek (1876, p. 405), were intended for the specimen 10a, d in case it was proved not to belong to *B. asper*, and, therefore, it is preferable not to use these for Meek's specimen, figures 10b, c. Therefore, the new name *meeki* is proposed for the latter and for the specimen from Beecher Island with which it is identical. The suture of *B. meeki* remains unknown.

Meek's specimen 10a, d, which is a true *B. asper*, possibly did not come from the Fox Hills formation at all, as, according to the new data, the species appears to be restricted to the lower part of the Pierre and to related formations.

Occurrence. In Beecher Island shale member, Yuma county, Colorado. According to Meek, near the top of the Fox Hills in South Dakota.

SUBFAMILY TURRILITINÆ

Genus HETEROCERAS d'Orbigny

Heteroceras tortum Meek and Hayden

(Plate XLII, fig. 2)

1858. *Helicoceras tortum*, Meek and Hayden, Proc. Acad. Nat. Sci. Phila., vol. 10, p. 54.
1864. *Heteroceras tortum*, Meek, Smithsonian Check-List N. Am. Cret. Fossils, p. 25.
1876. *Heteroceras tortum*, Meek, U. S. Geol. Survey Terr. Rept., vol. 9, p. 481, pl. 22, figs. 4a, b, c.

The writer has little doubt that a fragmentary specimen collected from Wallace county belongs to this species of Meek and Hayden. The size of the shell, the number and prominence of transverse ribs, the presence of one or possibly of two rows of not prominent nodes and the wide umbilicus are much like the features of the type described and figured by Meek.[30] The nodes are spaced as widely as in Meek's type, every second or every third rib provided with a node. Only very incomplete sutures can be observed in some portions of the Wallace county specimen.

Distribution. Meek refers this type to the "lower part of the Fort Pierre group." [31] The Wallace county specimen came also from the basal portion of the Pierre as there represented; from the top of the Sharon Springs shale member, where it was found in a limestone lens. According to Reeside "this type of shell does not occur in lower Pierre." [32]

30. Meek, 1876, p. 481, pl. 22, figs. 4a, b, c.
31. Meek, 1876, p. 482.
32. Personal note to the writer of April, 1931.

FAMILY COSMOCERATIDÆ

SUBFAMILY SCAPHITINÆ

Genus SCAPHITES Parkinson

Scaphites plenus Meek

(Plate XXXVI, figs. 1a, 1b, 1c, 2a, 2b, 2c; Plate XXXVII, figs. 1a, 1b, 1c; Plate XXXIX, figs. 1a, 1b, 1c; Plate XL, figs. 3, 4, 5, 6)

1860. *Scaphites nodosus* var. *plenus*, Meek and Hayden, Proc. Acad. Nat. Sci. Phila., p. 420.

1876. *Scaphites nodosus* var. *plenus* Meek, U. S. Geol. Survey Terr. Rept., vol. 9, p. 429, pl. 26, figs. 1a, b, c.

1885. *Scaphites subglobosus* Whiteaves, pars., Geol. Survey Canada, Contr. Can. Paleontology, vol. 1, p. 52, pl. 8, figs. 2, 2a. (Not pl. 7, fig. 3; pl. 8, figs. 1, 1a.)

1905. *Scaphites nodosus* var. *plenus*, Smith (W. D.), Jour. Geol., vol. 13, pp. 638, 644, 647-648; fig. 1 (p. 641) and figs 3-7, 8, 10 (p. 645).

1917. *Scaphites subglobosus* Dowling, pars., Geol. Survey Canada, Mem. 93, p. 32, pl. 31, figs. 2, 2a. (Not pl. 31, figs. 1, 1a. Reprints of Whiteaves' drawings.)

1927. *Acanthoscaphites nodosus* var. *plenus*, Reeside, U. S. Geol. Survey Prof. Paper 150-B, p. 32.

The following is the complete quotation of Meek's description of this interesting form: [33]

"This form differs from the typical *Scaphites nodosus*, not only in its proportionally shorter deflected body-part, but also in its much more gibbous form, and in the smaller size of its inner rows of lateral nodes, which are placed nearer the umbilical side. It also sometimes shows a slight tendency to develop a third intermediate series of very small lateral nodes about midway between the other rows, such as I have not seen in any of the other varieties.

"This tendency, however, is only manifested by a scarcely perceptible swelling of the costæ at this point, and consequently escaped the attention of the artist in drawing the figures; while even this faint tendency is not constant.

"Compared with the foregoing forms regarded as varieties of *S. nodosus*, this shell also presents a remarkable contrast, both in form and size. So great, indeed, is the difference that it seems difficult to believe that it can be properly regarded as even a marked variety of the same species as that represented by our figures 2, a, b, of plate 25; and, although I continue here to range it provisionally as a variety of *s. nodosus*, I am not altogether free from doubts on this point. Still, when we come to compare it with Owen's figure of the typical *s. nodosus*, and with the intermediate forms represented on our plate 25, little is found to distinguish it from the same, excepting its very ventricose form, a character not alone generally reliable for distinguishing species in this and allied groups of shells. Its septa will be observed to agree almost exactly, excepting in mere minute individual details, with those of the variety *brevis*, figured on plate 25, and to present the same differences in the smaller lobes from the variety *quadrangularis*, that the variety *brevis* does. At one time I was rather inclined to think that this great difference in the convexity of these shells might be merely sexual; but the fact that the variety or species *plenus* was only found at a locality on Yellowstone ~~river (where it occurs~~ associated

33. Meek, 1876, pp. 429, 430.

with some of the more compressed forms), while no specimens of it were found at numerous other localities where the latter forms are common, does not seem to sustain this view."

The specimen from Wallace county illustrated here (Pl. XXXVI, figs. 2a, 2b, 2c) has been (and still is) compared by the writer with the smaller specimens of *s. subglobosus* Whiteaves. At the same time he came to a conclusion that the larger specimen of Whiteaves' should not be classified with the smaller ones and that Whiteaves was in error in doing so. Inasmuch as the species established by Whiteaves was compared by Stanton [34] with *S. mullananus* Meek and Hayden, the writer felt justified in restricting the name *subglobosus* to the smaller specimens (Pl. 8, figs. 2, 2a) of Whiteaves, which certainly do not resemble *mullananus*. Consequently, he felt justified to identify the specimen from Wallace county with the smaller specimens of *S. subglobosus*. However, in discussing the matter with J. B. Reeside, the latter has advised the writer that he "examined the younger stages of *nodosus* var. *plenus* and found them to duplicate Whiteaves' figures of the supposed young of *subglobosus*." To this he added his opinion, which confirms the writer's view, that "Whiteaves was in error in supposing his small specimens to be the young of his larger specimens."[35] Subsequently Reeside has very obligingly supplied the writer with a squeeze of the inner whorl of a large specimen that agrees exactly with *subglobosus*, a cast of the holotype of *S. nodosus* var. *plenus* M. and H. and two younger individuals of the latter form from South Dakota. The examination of this material convinces the writer of the correctness of Reeside's view that both the smaller specimens of Whiteaves and the specimen from Wallace county represent younger individuals of *S. plenus*. Consequently the name *subglobosus* must be restricted to the large individual of Whiteaves' species only (Whiteaves' Pl. 7, fig. 3, and Pl. 8, figs. 1, 1a), and not to one small individual described by Whiteaves under one name, *subglobosus*.

Inasmuch as Meek illustrated only one large adult specimen of *plenus*, in which the inner volutions are hidden inside of the outer whorl, it is appropriate to illustrate and describe here the younger stages of the shell, which seem to be found more often in the Pierre shale than the complete large specimens with their living chamber preserved.

One of the most important results of the study of these earlier stages of *plenus* is the disclosed fact that the shell is wider than

34. Stanton, 1893, p. 189.
35. Letter to the writer, November 13, 1930.

high in all stages of growth. In this respect *plenus* differs considerably from all varieties of *Acanthoscaphites nodosus* (including the typical form), the shell of which is always higher than wide. This difference alone justifies the removal of *plenus* from *Acanthoscaphites nodosus*, a variety of which, though not without hesitation, it was considered by Meek.

The Wallace county specimen (Pl. XXXVI, figs. 2a, 2b, 2c) is round and much inflated; the maximum width is 20 mm.; the larger diameter is 35 mm. Volutions are broadly rounded on the periphery and on the lateral side, but are much more narrowly convex on the inner or umbilical side. The preserved nonseptate portion of the shell equals about one-third of a volution. Ribs are prominent, slightly curved toward aperture on the sides of shell and nearly or quite straight on the periphery. The ribs increase in number from the umbilicus to the periphery by intercalation of additional ones, two extra ribs being usually well developed at the row of peripheral nodes. On the rounded ventral portion of the shell, between the two rows of the peripheral nodes, an extra rib is added at each node, which brings the total number of ribs on the venter to about 34 on the half of the outer volution, as against 9 at the corresponding part of the shell of the umbilicus. The nodes occur in one row only on each side and are moderately prominent, every third, or rarely every second, of the lateral ribs being provided with a node. Inner volutions are also provided with the peripheral rows of nodes which begin to appear when the radius of volutions reaches about 5 mm.

The smallest specimens described as *S. subglobosus* by Whiteaves[36] resemble in every respect the above-described specimen from Wallace county. The ribs of Whiteaves' specimen are as much curved and nearly as densely spaced as on the Kansas specimen. However, in the latter shell there are three to four times as many ribs at the periphery as at the umbilicus, whereas Whiteaves observed "twice or perhaps three times as many on the center of the periphery as on the umbilical margin . . . in half-grown and very young shells" of the Canadian material. However, the direct comparison of our shell with the sketch by Whiteaves (Pl. 8, fig. 2) shows not much difference, if any, in the number of the lateral ribs. The number of ribs counted on the periphery of the same diameter for a volution is about 34 on the half-volution of this Kansas form and about 27 on the half-volution of the Canadian specimen (counted on the sketch on the left half of the outer volution, Pl. 8, fig. 2, of Whit-

36. Whiteaves, 1885, pl. 8, figs. 2, 2a.

eaves' paper). The nodes on our specimen are as prominent and as distantly spaced as in the Canadian type, in average about every fourth rib being provided with a node. The peripheral nodes are also noticed on the inner volutions of the Kansas specimen, which agrees with the characteristic given by Whiteaves, who noticed the nodes in the specimens "about two inches in their greatest diameter and in still smaller ones." All these smaller specimens of *S. subglobosus* Whiteaves must be now considered young stages of *S. plenus*.

The specimen (18907) from Pierre of the Black Hills (Pl. XXXVI, figs. 1a, 1b, 1c) is identical in almost every respect with *S. plenus* from Wallace county, but it has a somewhat smaller umbilicus and same minor differences in sutures. The larger specimen from western South Dakota (Pl. XXXVII, figs. 1a, 1b, 1c; Pl. XXXIX, figs. 1a, 1b, 1c) is somewhat more gibbous and the ribs of this shell are slightly coarser and more distantly spaced than in the other two shells above described. For instance, there are only 26 peripheral ribs to the half volution with diameter about 30 to 35 mm., while in the shell from Wallace county, which has the same diameter, there are 34 ribs. However, this difference is not very important and, when considered alone, hardly justifies separation of the western South Dakota shell as a variety of *S. plenus*. The size of the umbilicus of the form from South Dakota is comparable to that of the specimen from the Black Hills (18907).

Meek illustrated and described only the outer part of the suture of *plenus* (see Pl. XL, fig. 6). The material at hand permits study of the complete suture of this species on all three individuals (Pl. XL, figs. 3, 4 and 5) here described. The sutures of these individuals are not exactly alike, but their differences do not seem to be so important as to prevent consideration of the three as specifically identical. Possibly they may be regarded as varieties of *plenus*, but one must verify the constancy of those differences which seem sufficient for a separation of a variety on more material than that at the writer's disposal. The general design, the number of larger lobes and saddles and the character of dissection of the suture of the described specimens are fairly identical.

Meek pointed out the similarity of the sutures of *plenus* with those of *S. nodosus* var. *brevis*. Though admitting the similarities as pointed out by Meek, the writer sees the following common features in the sutures of Meek's type of *plenus* and of the shells here described which may serve for their distinction from the *nodosus* group:

(1) The general outline of the first lateral saddle is nearly square in both var. *brevis* and var. *quadrangularis* of *nodosus* group (see Pl. 25, figs. 1c, 2c, 3c, Meek, 1876). A square outline of this saddle is shown also by the type specimen of *S. nodosus*.[37] Contrary to this the first lateral saddle of *S. plenus* has an oval outline with outer branch much shorter than the larger inner branch; see the suture of the type of *S. plenus* (Pl. XL, fig. 6) and the sutures of all specimens here described (Pl. XL, figs. 3, 4 and 5).

(2) The second lateral lobe of *brevis* and *quadrangularis* is fairly symmetrical and is divided into two equal or nearly equal branches, each of which is in turn distinctly bipartite. The corresponding second lateral lobe of *S. plenus* has its outer branch always more digitate than the inner branch (see all sutures of the species here illustrated). Owing to this, the second lobe has an appearance of being subdivided into three branches (see the sutures of the specimens here described, Pl. XL, figs. 3, 4 and 5).

There seem to be no particular points of distinction between the inner part of the suture of *S. plenus* and the inner part of the suture of the specimens of *A. nodosus* of the writer's collection.[38]

Novak placed *nodosus* Owen and its varieties as established by Meek in the genus *Acanthoscaphites*, while Reeside expresses his opinion in this matter in the following way:

> "Whether all the forms customarily placed in the species *nodosus* Owen belong to *Acanthoscaphites* may be doubted, but this comprehensive species needs extensive revision before much can be said of it with confidence, and in the meanwhile it may be left as Novak assigned it."[39]

The writer did not make any revision of the whole *nodosus* group, but his material on *plenus*, supplemented by the specimens sent to him by Reeside, permits him to conclude that *plenus* does not belong to *Acanthoscaphites*, but must be placed in *Holcoscaphites* Novak, which is a synonym of *Scaphites* in the proper sense. The following are the features of *plenus* which are characteristic of the latter genus:

(1) The shell is wider than high, which holds true in all stages of growth.

(2) In the young stages of the shell the outer sculpture is pre-

37. Owen, 1852, pl. 8, fig. 4a. Meek justly remarks that Owen's "figure of a septum" of *nodosus* "is evidently not drawn with sufficient completeness and accuracy of detail," but the first lateral saddle of Owen's drawing, which shows a square outline comparable to that of *brevis* and *quadrangularis*, seems to be more accurately drawn than the rest of the suture.

38. The writer does not know of any published illustrations of the inner part of the sutures of *A. nodosus* or its varieties.

39. Reeside, 1927, p. 27.

cisely of the type which is considered typical for *Scaphites:* "the ribs pass without nodes from the umbilicus, end at the edges of the venter with a nodose thickening and then split into weaker, secondary ribs."[40]

The suture of *plenus* is of the type of *S. aequalis* Sowerby except that the second lateral lobe is much shorter than the first lateral lobe, while according to Novak the lobes of *Holcoscaphites* (= *Scaphites*) decrease in size gradually. However, it must be added that in the suture which is next to the living chamber in the specimen of *S. plenus* from Wallace county (Pl. XL, fig. 5), the first lateral lobe is only slightly higher than the second lobe, while in the next suture (not illustrated here) the first lobe is much higher than the second. It seems as if the difference in the sutures of this sort may be considered of lesser importance than the differences in the shape and sculpture of the shells of *Scaphites* group. The genus *Yezoites*, based by Yabe on some peculiar characters of the internal (dorsal) part of the suture in some Japanese species, is not regarded valid either by Novak or by Reeside.

In conclusion the writer would say that inasmuch as he did not have an opportunity to revise the whole group *nodosus* Owen he leaves open to question the generic relation between *plenus* and the rest of the shells of the *nodosus* group; he thinks, however, that there is enough evidence at hand to make *plenus* a distinct species. The possibility of such separation of *S. plenus* Meek from the rest of the *nodosus* group was foreseen by Meek himself,[41] while Reeside also holds the view that "there is warrant" to do so.[42]

Occurrence. The specimen of *S. plenus* was found in the concretionary limestone zone at the base of Salt Grass shale member in Wallace county. The type specimen of *S. plenus* is referred by Meek to the "upper part of the Fort Pierre group of the Upper Missouri Cretaceous series."[43] Canadian specimens are referred to the Fox Hills sandstone north of Wood Mountain, Alberta.[44] It appears as if *S. plenus* is characteristic of somewhat higher horizons of the Pierre than *A. nodosus* and its varieties *brevis* and *quadrangularis.*

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40. Reeside, 1927, p. 24, definition of genus *Holcoscaphites* (= *Scaphites*) translated after Novak.

41. Meek, 1876, pp. 429, 430.

42. Letter to the writer of December 9, 1930.

43. Meek, 1876, p. 430.

44. Ann. Rept. Geol. Survey Canada, vol. 1, p. 46 C, also Dowling, 1917, p. 32. According to Reeside [illegible] "[illegible] Hills" is not true Fox Hills, but a sandy Pierre horizon (personal note of April, 1931).

Genus ACANTHOSCAPHITES Novak

Acanthoscaphites nodosus (Owen) (1852)

This species of Owen and its varieties *brevis* and *quadrangularis* established by Meek are the most common scaphites of the Pierre in Kansas. However, complete and undistorted specimens of this form are very rare and, in nearly every case, the species or its varieties were identified on fragments of various size. In spite of the fragmentary occurrence, this important index fossil of the Pierre can be nearly always identified with a fair degree of accuracy, its comparatively large size, coarseness of costæ and prominence of nodes being very characteristic.

Acanthoscaphites nodosus (Owen) s. s.

(Plate XXXVIII, figs. 1a, 1b, 2, 3)

1852. *Scaphites (Ammonites) nodosus*, Owen, Report Geol. Survey Iowa, Wis. and Minn., p. 581, pl. 8, fig. 4.

1892. *Scaphites nodosus*, Whitfield, U. S. Geol. Survey, Mem. 18, p. 261, pl. 44, figs. 13, 14.

1896. *Scaphites nodosus*, Gilbert, U. S. Geol. Survey, 17th Ann. Rept., pt. 2, pl. 65, fig. 2.

1905. *Scaphites nodosus* Owen, Smith (W. D.), Jour. Geol., vol. 13, pp. 638, 648.

1907. *Scaphites nodosus* Owen, Weller, Rept. Cret. Pal. New Jersey, Geol. Surv. New Jersey, Pal., vol. 4, p. 824, pl. 107, figs. 1, 2.

1916. *Acanthoscaphites nodosus* (Owen), Novak, Die Bedeutung von *Scaphites* für die Gliederung der ober Kreide: K. -k. geol. Reichsanstalt Verh., Jahrg. 1916, w. 3, p. 63.

1927. *Acanthoscaphites nodosus*, Reeside, U. S. Geol. Survey, Prof. Paper, 150-B, p. 32.

Owen describes the type of the species as follows: [45]

"Shell large and ponderous. Volutions subcylindrical, enlarging gradually towards the terminal chamber. Surface ornamented with sinous costæ, most of which bifurcate at different distances from the umbilicus and, thus multiplied, proceed across the dorsum. Two rows of very prominent tubercles. The row near the periphery especially large and prominent, and from one-half to three-quarters of an inch apart. Aperture subovate. Greatest diameter, four inches; greatest thickness, two and a half inches."

The following characteristic features of the typical form as compared with its variety *brevis* and *quadrangularis* were used by the writer in identification of his material from the Pierre of Wallace county: (1) Larger size; (2) costæ of both periphery and sides are more distant than in *brevis* and *guadrangularis;* (3) both lateral nodes and peripheral nodes are equally prominent and nearly equidistantly spaced; (4) the row of nodes corresponding to the umbilical nodes of var. *brevis* and var. *quadrangularis* in the typical *nodosus* is nearly in the middle of the flank of the shell.

45. Owen, 1852, p. 581.

Occurrence. In the upper half of the Upper Weskan member and in the Lake Creek member of the Pierre shale of Wallace county. Owen's type specimen came from the upper part of the Pierre from near Cheyenne river, South Dakota.[46] The specimen figured by Gilbert came from "Tepee butte"-zone of the Pierre of Arkansas river, Colorado. According to Reeside [47] the species belongs to the upper, as compared to the lower, part of the Pierre.

Acanthoscaphites nodosus var. *brevis* Meek

(Plate XXXVI, fig. 2; Plate XLI, fig. 3)

1876. *Scaphites nodosus* var. *brevis*, Meek, U. S. Geol. Survey Terr. Rept., vol. 9, p. 426, pl. 25, figs. 1a, b, c.

Not 1905. *Scaphites nodosus* var. *brevis* Smith (W. D.), Jour. Geol., vol. 13, pp. 638, 640-649, fig. 1-2 (p. 641).

1927. *Acanthoscaphites nodosus* var. *brevis*, Reeside, U. S. Geol. Survey, Prof. Paper 150-B, p. 32.

Meek states that: [48] "This shell differs from Doctor Owen's type of his *S. nodosus* in having its nonseptate part deflected portion of the last volution much shorter, and its inner volutions more compressed, while the nodes near its umbilicus are decidely smaller."

The writer would add to this that the costæ of var. *brevis* are more closely spaced than in the typical *A. nodosus* and that the lateral row of nodes in the former is closer to the umbilicus than in the latter form: "along about one-third the height from the umbilicus" in var. *brevis*.[49] Furthermore, there are only a few (three on fig. 1b of Meek's monograph) and smaller nodes at the umbilicus of var. *brevis*, while the lateral nodes are numerous (8 or more) in the typical *A. nodosus* and at least the middle nodes of the row are not less prominent than the peripheral nodes of the species.[50]

Occurrence. In the Lake Creek member and at the base of the Salt Grass member of the Pierre shale in Wallace county; possibly also in the Upper Weskan shale member. The type of the variety came from the upper part of the Pierre on Yellowstone river, Montana.[51] In the Upper Pierre according to Reeside.[52]

46. Meek, 1876, p. 428.
47. Reeside, 1927, p. 32.
48. Meek, 1876, p. 427.
49. Meek, 1876, p. 427.
50. Compare Owen, 1852, pl. 8, fig. 4.
51. Meek, 1876, p. 428.
52. Reeside, 1927, p. 32.

Acanthoscaphites nodosus var. *quadrangularis* Meek and Hayden

(Plate XXXVII, fig. 3)

1860. *Scaphites nodosus* var. *quadrangularis* Meek and Hayden, Proc. Acad. Nat. Sci. Phila., vol. 12, p. 420.

1860. *Scaphites nodosus* var. *exilis* Meek and Hayden, Proc. Acad. Nat. Sci. Phila., vol. 12, p. 420.

1876. *Scaphites nodosus* var. *quadrangularis*, Meek, U. S. Geol. Survey Terr., Rept., vol. 9, p. 428, pl. 25, figs. 2a, b, c; 3a, b, c and 4.

Not 1905. *Scaphites nodosus* var. *quadrangularis*, Smith (W. D.), Jour. Geol., vol. 13, pp. 638, 640-649, fig. 1-3 (p. 641).

1927. *Acanthoscaphites nodosus* var. *quadrangularis* Reeside, U. S. Geol. Survey, Prof. Paper 150-B, p. 32.

According to Meek this variety differs from var. *brevis* "not only in its usually smaller size, but also in having its periphery flattened, its umbilicus rather large, and its body part narrower in its vertical diameter, as well as less straightened along its upper margin. Its inner row of nodes will also be seen to be nearer the umbilical margin, and the outer rows near the periphery; the latter character being, of course, due to the flattening of the periphery. There will also be seen to be some slight differences in the details of its septa, particularly in the form of its third lateral lobe, and the presence of a small fourth lateral.

"Compared with Doctor Owen's typical form of *S. nodosus* it will be seen to differ even more strongly than the last, in form and several other respects."

The smaller size, the presence of a number of rather prominent nodes at the umbilicus and subquadrate cross section are the chief characters used for identification of this variety of *A. nodosus* in the Pierre of Wallace county.

Occurrence. In the Upper Weskan and in the Lake Creek shale members of Wallace county Pierre; also at the base of the Salt Grass shale member. In the upper part of the Pierre on Yellowstone river, Montana, according to Meek.[53] In the upper Pierre according to Reeside.[54]

Acanthoscaphites (?) *reesidei* Wade

1926. *Scaphites reesidei* Wade, U. S. Geol. Survey, Prof. Paper 137, p. 183, pl. 61, figs. 3-7.

1927. *Acanthoscaphites* (?) *reesidei*, Reeside, U. S. Geol. Survey, Prof. Paper 150-B, p. 33.

A good and nearly complete (except living chamber) specimen of this rare species was found by the writer in Wallace county in 1927. Unfortunately, the specimen is not now at his disposal and therefore it can be neither illustrated nor described. The specimen

53. Meek, 1876, p. 429.

54. Reeside, 1927, p. 32.

was compared by the writer in 1928 with the figures and descriptions by Wade and was found to agree with the figure of the type in every respect, including the character of the suture.

Occurrence. In limestone concretionary zone at the base of the Salt Grass shale member in Wallace county. The type specimen of *A. reesidei* came from the Coon creek locality of the Ripley formation in Tennessee.

Genus DISCOSCAPHITES Meek

cf. *Discoscaphites* (?) *constrictus* Sowerby var. *tenuistriatus* (Kner)

(Plate XXIX, fig. 3; Plate XXXIX, fig. 10)

Compare 1908. *Scaphites constrictus* Sowerby, Grossouvre, Mem. Mus. Royale D' Hist. Nat. Belgique, p. 36, pl. 11, fig. 6.

Compare 1911. *Hoploscaphites constrictus-tenuistriatus* Novak, Acad. Sci. Cracovie Bull. internat., sér. B, p. 585, pl. 33, figs. 13, 21 and 22.

Though the writer realizes that an identification of European species among the American Upper Cretaceous forms must be made with caution, he nevertheless compares provisionally fragmentary remains from Wallace county with some illustrated shells of the *constrictus* type from Europe, because the Wallace county remains differ from all American Upper Cretaceous amonities so far described. Their size is small, they are considerably compressed, their surface is marked by fine ribs and they have a small umbilicus.

In all these respects the remains are comparable to *Discoscaphites nicolleti* Morton, but not the faintest trace of tubercles of any kind can be observed on the specimens from Wallace county. It is interesting to note that Meek [55] compared *D. nicolleti* with some tuberculate varieties of *Scaphites constrictus* Sowerby from Europe, as illustrated by d'Orbigny,[56] and according to Novak both tuberculate and nontuberculate forms exist among the shells which he refers to *S. constrictus* var. *tenuistriatus*, with which the specimens from Wallace county have so much in common. Thus it appears as if we might extend the conception of *D. nicolleti* so as to include nontuberculate forms, which otherwise differ little or not at all from the typical *nicolleti*. This, however, is not advisable for the following reasons:

(1) The presence of peripheral tubercles is mentioned in the original characterization of the type specimen of *nicolleti* Morton.[57]

(2) The stratigraphic position of true *nicolleti* is Fox Hills and the upper part of the Pierre. Though the writer collected this species

55. Meek, 1876, [illegible]

56. Paléont. Fr., Terr. Cret., I, pl. 129, fig. 8.

57. 1842, p. 209, though tubercles are not shown on the much generalized sketch, pl. 10, fig. 3.

in Wallace county as low as at the top of the Salt Grass shale member, which is about in the middle of the Pierre, he considers the Salt Grass specimens a new variety of *nicolleti*, which is described below (this variety is tuberculate). The remains here compared with the nontuberculate varieties of European *constrictus* have been collected as low in the Pierre as in the Lower Weskan shale member, which is only about 200 feet above the base of the formation.

If, in the course of time, the identity of *nicolleti* with European *constrictus* is proved, there would be more reason to separate the nontuberculate European variety of *constrictus* as a distinct form, and not, contrary to this, mix up the American tuberculate and nontuberculate forms of the *nicolleti* type, which, as far as is established at present, do not occur together in the stratigraphic column of the North American Upper Cretaceous.

In view of all these considerations the nontuberculate remains here described should be given a new name. However, due to the imperfection of the remains from Wallace county and the badly preserved suture, the writer prefers to designate them temporarily as cf. *D. constrictus* var. *tenuistriatus*.

Occurrence. Two small individuals, the better of which is shown on Plate XXXIX, figure 10, came from limestone concretions of the Weskan shale, and probably from the Lower Weskan shale member. The larger individual of Plate XXIX, figure 3, was collected in the Upper Lake Creek shale member. All specimens were collected in Wallace county.

Discoscaphites nicolleti (Morton) Meek

1842. *Ammonites nicolleti* Morton, Acad. Nat. Sci. Phila, Jour., 1 ser., vol. 8, pt. 2, p. 209, pl. 10, fig. 3.

1852. *Ammonites nicolleti* Owen, Rept. U. S. Geol. Surv. Wisconsin, Iowa and Minnesota, pl. 8, fig. 1.

1852. *Scaphites (Ammonites) comprimis* Owen, ibid., p. 580, pl. 7, fig. 4.

1857. *Scaphites nicolleti* Meek and Hayden, Acad. Nat. Sci. Phila. Jour., vol. 8, p. 281.

1876. *Scaphites (Discoscaphites) nicolleti* Meek, U. S. Geol. Survey Terr., Rept., vol. 9, p. 435, pl. 34, figs. 2 and 4.

1927. *Discoscaphites nicolleti* Reeside, U. S. Geol. Survey, Prof. Paper 150-B, p. 31-32, pl. 9, figs. 5-7.

Meek gives the following definition of the species:

"Shell oval-subcircular, much compressed; volutions so deeply embracing as to leave only a small umbilicus, all strongly compressed laterally, inner ones narrowly rounded on the periphery; deflected part of last turn so very short as not to become free at the aperture, narrowly flattened on the periphery below, and somewhat widened and straightened along the upper margin near the umbilicus; aperture narrow-oval; surface ornamented by numerous small, somewhat flexuous costæ, which increase by division and intercalation so as

to number about five time as many around the periphery as at the inner side; costæ everywhere without tubercles or nodes, excepting a single row along each side of the flattened periphery of the outer volution, all crossing the periphery with a moderate forward curve.

"Length, 2.31 inches; height, 1.92 inches; convexity, about 0.62 inch."[58]

The suture of the species was unknown until the description by Meek. According to this author the suture of the species is much like that of *Scaphites conradi* var. *intermedius*, which "holds almost an exactly intermediate position, as it were, between the typical *S. conradi* and *S. nicolleti* Morton (= *S. comprimis* Owen), both in external and internal characters."[59]

Though Meek points out some minor differences in the sutures of *S. nicolleti* and *S. conradi* var. *intermedius*, he says that "these differences in the details of the lobes and sinuses of the septa are not, it must be confessed, very important, or even not greater than we may frequently see between those of different individuals of the same species."[60] Meek furthermore stresses the differences in the sculpture between the *conradi* and *nicolleti* groups and points out the "entire absence of tubercles on the sides of all the volutions, both inner and outer"[61] of the *nicolleti* form. In this respect the "shell departs from the *Discoscaphites* group," but "from its close general relations to the last, however, in which that character does occur, both in form and in the details of the septa, it seems improper to place it in any other section."[62]

It is interesting to point out that in Owen's *Scaphites comprimis*, which Meek classifies with *D. nicolleti*, there is a row of "more obscure tubercles, one-fourth of the distance from the inner margin of the convolutions,"[63] which are also shown on Owen's sketch. Since the outer sculpture is an important feature in classification of the species of the *Discoscaphites* group, it appears that Owen's type may possibly be a variety of *D. nicolleti*, having not only an additional row of tubercles but also a somewhat different arrangement of costæ. As will be shown below, the specimens of *D. nicolleti* from Wallace county have more distantly spaced marginal costæ than in the specimens described by Meek. There are again some differences in the outer sculpture as well as in the suture line, which permit the separation of this as a new variety of the *nicolleti* type.

58. Meek, 1876, p. 435.
59. Meek, 1876, p. 434.
60. Ibid., p. 434.
61. Ibid., p. 436.
62. Ibid., p. 436.
63. Owen, 1852, p. 580.

Occurrence. According to Meek the species was found in the Fox Hills group in South Dakota and Montana. The specimen illustrated by Reeside came from the top of the Pierre shale at Linton, North Dakota.

Discoscaphites nicolleti var. *saltgrassensis* Elias, n. var.

(Plate XXXVI, figs. 3a, 3b, 3c; Plate XL, fig. 1)

The variety differs from *D. nicolleti* as described by Meek in having the marginal tubercles not on every costæ as shown in Meek's monograph (Pl. 34, fig. 26).[64] On the shell of var. *saltgrassensis* the tubercles begin to appear when the radius of the volutions approaches 15 mm. At this radius each fourth of the peripheral costæ has a tubercle, but soon, at about 20 mm. radius of the volutions, each third costæ has a tubercle, while Meek shows a tubercle on every peripheral costa at 23 to 25 mm. radius.[65] The number of the costæ of the specimens as figured by Meek appears to be about the same as on the specimens from Wallace county. Meek does not give any figures for the number of the Costæ on the periphery, which for our variety is 10 to 11 per 1 cm. at the radius of 15 mm. and is about 7 per 1 cm. at the end of the next half of a complete volution or at about 25 mm. radius. The shape of the variety is the same as in the specimens figured by Meek, the periphery of the volutions being broadly rounded (as on Meek's Pl. 34, fig. 46, and not as on Pl. 34, fig. 26, where the periphery is shown to be nearly acute at the end of the preserved volutions).

The suture of the variety differs in one respect more from that of *D. nicolleti* Meek than the latter differs from the suture of *D. conradi* var. *intermedius*. The first lateral saddle of var. *saltgrassensis* is oval in outline while this saddle has a nearly square outline in both *D. nicolleti* Meek and *D. conradi* var. *intermedius* Meek. In other words, while the three branches of the first saddles in the two latter types are nearly equal in height, the central branch of the first saddle of var. *saltgrassensis* is the highest, while the lateral branches and branchlets slope down, gradually filling a perfectly oval outline of the saddle (see Pl. XL, fig. 1, of this report). However, this and some other minor differences in the suture of var. *saltgrassensis* are not very important and, if not supported by differences in the sculpture, would not justify the separation of the variety *saltgrassensis* from typical *D. nicolleti*.

64. Meek, 1876.
65. Ibid., pl. 34, fig. 26.

The lower stratigraphic position of the var. *saltgrassensis* at the middle of the Pierre formation is another point in favor of its separation as a distinct variety of *D. nicolleti,* which belongs to the Fox Hills beds and to the top of the Pierre shale.

It is interesting to add that the suture of *D. nicolleti* from the top of the Pierre at Linton, South Dakota, as figured by Reeside (1927, Pl. 9, fig. 7) is closer to that of var. *saltgrassensis* than to the typical form as shown by Meek.

Occurrence. The variety was found in a lens of typical "*Lucina* limestone" at the top of the Salt Grass member of the Pierre in Wallace county in the center of sec. 2, T. 12 S., R. 42 W.; thus stratigraphically the variety belongs to the middle of the Pierre as represented in northwestern Kansas. It appears that the first appearance of the *Discoscaphites nicolleti* in the Pierre of the Central High Plains belongs to this horizon. At the base of the Salt Grass member, or only about 50 to 60 feet stratigraphically below the beds with *D. nicolleti* var. *saltgrassensis,* the typical representatives of the *Acanthoscaphites* group, such as *A. nodosus* var. *brevis* and var. *quadrangularis* and also *Acanthoscaphites* (?) *reesidei* and *Scaphites plenus,* were collected. A small scaphite, very similar to var. *saltgrassensis,* was also collected in the "Lucina limestone" cores at the base of the Salt Grass member, but these specimens were not preserved well enough for precise identification.

Discoscaphites conradi (Morton)

(Plate XXXIX, figs. 9a, 9b)

1834. *Ammonites conradi,* Morton, Synopsis of organic remains of Cretaceous group of the U. S. A., p. 39, pl. 16, figs. 1-3.

1850. *Scaphites conradi,* d'Orbigny, Prodrôme de Paléon., p. 214.

1871. *Scaphites* (*Discoscaphites*) *conradi,* Meek, Am. Phil. So., Proc., vol. 11, p. 429.

1876. *Scaphites* (*Discoscaphites*) *conradi,* Meek, U. S. Geol. Survey Terr., Rept., vol. 9, p. 430, pl. 36, fig. 2.

1916. *Scaphites conradi,* Gardner, Maryland Geol. Survey, Upper Cretaceous, p. 383, pl. 12, fig. 1.

1927. *Discoscaphites conradi,* Reeside, U. S. Geol. Survey, Prof. Paper 150-B, p. 28.

A fragment which undoubtedly belongs to this form was found in the Beecher Island shale and identified by the writer in 1928. The species was recognized by the discoidal form and by the presence of three to four rows of nodes on the outer part of the flanks of the shell. These nodes were located on the costæ of the outer sculpture. The size of the shell as judged from the fragment is suggestive of either *D. conradi* or *D. cheyennensis* of the North American *Discoscaphites,* while the comparative evenness of the venter resembles

that of former species. Among the so-far published illustrations of American *Discoscaphites* the shell from Beecher Island resembles most that figured by Gardner.[66] Another fragment of a smaller individual of *D. conradi* was found by the writer in 1930 and is here illustrated (Pl. XXXIX, figs. 9a, 9b).

Occurrence. In the Beecher Island member of the Pierre shale at Beecher Island, Colorado. The type species of *D. conradi* came from the Upper Cretaceous beds of Alabama.[67] According to Meek: "It also occurs at the same horizon in New Jersey,"[68] but no identical or related forms have been described in comprehensive monographs of the Upper Cretaceous fauna of New Jersey by later authors.[69] Stephenson records *D. conradi* in the *Exogyra costata* zone of the Eastern Gulf region and in the *Liopistha protexta* subzone at the top of Selma chalk in western Alabama and east-central Mississippi.[70]

Meek has "seen specimens of it from Saskatchewan, British America, in Professor Hind's collections." The specimens described by Meek came from the "Fox Hills group at Fox Hills, Long Lake, Moreau river and near the eastern base of the Black Hills, Dakota."[71]

Gardner described the species from the Monmouth formation of Maryland.[72] According to Reeside the species occurs in the Fox Hills sandstone, which he compares with the Mæstrichtian of Europe.

Discoscaphites abyssinus (Morton)

(Plate XXXIX, figs. 2, 3, 4, 5, 6a, 6b, 7, 8; Plate XL, fig. 2)

1841. *Ammonites abyssinus* Morton, Jour. Acad. Nat. Sci. Phila., vol. 8, p. 209, pl. 10, figure 4.

1856. *Scaphites mandanensis?* Meek and Hayden, Proc. Acad. Nat. Sci. Phila., vol. 8, p. 281.

1860. *Scaphites abyssinus* Meek and Hayden, Proc. Acad. Nat. Sci. Phila., vol. 12, p. 420.

1864. *Scaphites abyssinus* Meek and Hayden, Smithsonian Check-List of North American Cretaceous Fossils, p. 23.

1876. *Scaphites (Discoscaphites) abyssinus* Meek, Invertebrate Cretaceous and Tertiary fossils of the Upper Missouri country, U. S. Geol. Survey Terr., Rept., vol. 9, p. 441, pl. 35, figs. 2a, b and 4.

1927. *Discoscaphites abyssinus* Reeside, Scaphites, an Upper Cretaceous Ammonite group, U. S. Geol. Survey, Prof. Paper 150-B, pp. 27, 36.

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66. Gardner, 1916, pl. 12.
67. Morton, 1834, p. 39.
68. Meek, 1876, p. 432.
69. Whitfield, 1886 and 1892; Weller, 1907.
70. Stephenson, 1914, pp. 36-37.
71. Meek, 1876, p. 432.
72. Gardner, 1916, p. 383, pl. 11.

Meek gives the following definition of the species: [73]

"Shell short-oval, or subcircular, much compressed; inner volutions deeply embraced within the dorsal groove of each succeeding turn; last whorl flattened on the sides and periphery, having a more or less distinct subnodose angle around the umbilicus, and on each side of the periphery; nonseptate portion short, not widened or straightened along its upper margin, and deviating so little from the regular curve of the inner whorls as to become but slightly disconnected from them at the aperture; umbilicus rather small; aperture oval or subcordate; surface ornamented by rather distinct, straight, or slightly flexuous costæ, which increase chiefly by the intercalation of shorter ones between the longer, so as to number from two to three times as many at the periphery as near the umbilicus; those on the inner whorls often supporting some three or more rows of very small nodes on each side, in addition to the larger series on each side of the narrow, flattened periphery.

"Septa divided into three or four lobes and as many sinuses on each side of the siphonal lobe, which is of an oblong form, being a little longer than wide, with two principal branches on each side, the two terminal of which are slender, larger than the others, nearly parallel, obscurely bifid, and provided with a few obtuse, short digitations or crenulations; while the lateral branches are short and spreading, the larger pair being merely obtusely tridentate, and the others simple; first lateral sinus as long as the siphonal lobe, and near one-fourth wider, with a nearly quadrangular form, and provided with two large unequal, irregular branches, with short, obtusely crenate subdivisions; first lateral lobe a little shorter than the siphonal, and of nearly the same breadth, with two branches on each side, the two terminal of which are of moderate length, spreading, bifid, and provided with obtusely crenate or dentate margins, while the two lateral branches are much smaller, directed out at right angles from the margins, and each obtusely tridentate at the end; second lateral sinus scarcely half as large as the first, and bearing two unequal, shortly bipartite or tripartite, deeply sinuous, and obtusely dentate terminal branches, and one or two unequal, short, nearly simple, lateral branchlets; second lateral lobe much like the first, but scarcely more than half as long and wide; third lateral sinus about one-third as large as the second, with two short, spreading, obtusely dentate, terminal branches; third lateral lobe very small and merely obscurely bilobate at the end; fourth lateral sinus as long as the third lateral lobe, but wider and faintly bilobate at the end; fourth lateral lobe slightly wider and longer than the third, but more distinctly trilobate at the end.

"Length, 2.09 inches; height, 1.65 inches; convexity, 0.63 inch.

"The angle around the inner side of the nonseptate part of the outer volution in this species is not always well marked, and varies a little in its distance from the umbilical margin. It is apparently always provided with a row of low prominences, like transversely-elongated nodes, that never exist on the inner volutions. The angle on each side of the narrow, flattened periphery, with its row of nodes, seems to be always well defined on the outer volution, excepting near the aperture, where both angles and nodes usually fade away and the costæ become finer and crowded. On the inner volutions, also, the

73. Meek, 1876, pp. 441, 442.

peripheral angles become obscure or obsolete, though their place is occupied by the rows of nodes reduced in size. The little nodes seen on the sides of the inner volutions, and sometimes on the inner half of the last turn, are placed on the costæ so as to form about three, nearly equidistant, revolving rows on each side of the shell."

The specimens which were collected in the Upper Pierre shale near Beecher Island and in the corresponding beds in northern part of Cheyenne county, Kansas, are somewhat smaller than the types figured by Morton and Meek and are slightly different in some other respects, which, however, do not seem to be so important as to warrant separation of the form collected from these localities from the typical species.

The fragment of Plate XXXIX, figure 8, represents the largest individual of the collection, which approaches in size Meek's types, while the nearly complete specimen (Pl. XXXIX, fig. 3) is only slightly smaller. It is interesting to note that in both these individuals the "low prominences like transversely elongated nodes" (Meek) are so insignificant as to be nearly absent. However, they are quite prominent on smaller individuals (Pl. XXXIX, figs. 2, 4, 7a). The small lateral nodes of the inner volutions seem to be absent in all specimens of the collection with the exception of one, in which only one row of lateral nodes (instead of three rows as according to Meek) is developed (Pl. XXXIX, fig. 4). However, the presence of lateral nodes is not a constant feature of the species. When comparing his material with Morton's type Meek remarked that the type specimen itself "showed none of the little nodes on the costæ of the sides of the shell" and that "these are not always present" on the material described by Meek. The suture of the form here described does not differ much from that shown by Meek for *D. abyssinus* (the suture of Morton's type is unknown). The main features which permit classification of the specimens from Beecher Island shale member with Morton's species are the general similarity in form and, to a certain extent, in size of the shells; the presence of prominent nodes on the periphery and at the umbilical margin of the outer volution; the change from rather prominent regular costæ to much finer and crowded costæ at the outer part of the aperture; the very narrow umbilicus. The suture is quite typical for the species (see Pl. XL, fig. 2).

To the characterization of the species given by Meek may be added that the living chamber, as noted on the material here described, occupies a little more than one-half of a volution.

Distribution. In the Beecher Island shale member of the Pierre in sec. 8, T. 2 S., R. 43 W., Yuma county, Colorado, and in the corresponding beds in NE¼ sec. 9, T. 2 S., R. 42 W. and in NE¼ sec. 5, T. 1 S., R. 39 W. of Cheyenne county, Kansas.

According to Meek the specimens from Moreau river, South Dakota, belong to the "Fox Hills group."

SUBFAMILY PLACENTICERATINÆ

Genus PLACENTICERAS Hyatt

Placenticeras meeki Boehm

(Plate XLI, figs. 1a, Ib, 2; Plate XLII, figs. 1a, 1b)

1876. *Placenticeras placenta,* Meek, U. S. Geol. Survey Terr., vol. 9, p. 465, text fig. 65; pl. 24, fig. 2.

1898. *Placenticeras meeki* Boehm, Deutsche Geol. Gesell. Zeitschr., vol. 50, p. 200 (footnote).

1903. *Placenticeras whitfieldi* Hyatt, U. S. Geol. Survey, Mon. 44, p. 221, pl. 45, figs. 3-16; pl. 46; pl. 47, figs. 1-4.

1910. *Placenticeras whitefieldi* Grabau and Shimer, North American Index Fossils, p. 218, figs. 1493, 1494.

1927. *Placenticeras meeki,* Reeside, U. S. Geol. Survey, Prof. Paper 151, p. 29, pl. 22, figs. 5-7; pl. 23; pl. 24; pl. 25, figs. 1-2.

This large *Placenticeras* is common in the Pierre of Wallace county, where no other species of the genus have been found by the writer. The species was recognized by its large size, smooth non-tuberculate sides, compressed volutions, venter narrow in youth and moderately rounded in old age, narrow umbilicus and a very typical suture. For the detailed characteristics of the species see Hyatt [74] and Reeside.[75]

The remains collected in Wallace county represent shells of large to very large size. A nearly complete shell (Pl. XLI, figs. 1a, 1b, 2 and Pl. XLII, figs. 1a, 1b) approaches 18 inches in diameter with part of the living chamber preserved. The living chamber shows broadly undulated venter (Pl. XLII, fig. 1a).

Some fragments from Wallace county, which seem to belong to *P. meeki,* indicate that the species attained as large a size as 3½ feet in diameter.

Occurrence. In the lower and upper Weskan shale member and in the lower part of Lake Creek shale member of the Pierre in Wallace county. According to Reeside [76] this species "has been found widely distributed in the Pierre shale and equivalent formations of the Western Interior province of the American Cretaceous."

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74. Hyatt, 1903, p. 221.
75. Reeside, 1927, p. 29.
76. Reeside, 1927, p. 30.

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EXPLANATION OF PLATES

PLATE XXVIII

FIG. 1. *Baculites compressus* var. *reesidei* Elias, n. var. Side view. Natural size. For cross section and suture of this specimen see Pl. XXXIII, figs. 2b, 2c. From Lake Creek shale member, Pierre formation, center sec. 35, T. 11 S., R. 39 W., Wallace county, Kansas.

FIG. 2. *Baculites pseudovatus* var. A Elias, n. var. Side view of holotype. Natural size. For cross section and suture of this specimen see Pl. XXXIII, figs. 5a, 5b. From Baculites zone of Salt Grass shale member, Pierre formation, E. sec. 2, T. 12 S., R. 42 W., Wallace county, Kansas.

FIG. 3. *Baculites compressus* var. *corrugatus* Elias, n. var. Side view of type specimen. Natural size. For cross section and suture of this specimen see Pl. XXXII, figs. 1a, 1b, 1c. From Lake Creek shale member, Pierre formation, SE¼ sec. 29, T. 11 S., R. 39 W., Wallace county, Kansas.

FIG. 4. *Baculites compressus* Say (in restricted sense). Side view. Natural size. For cross section and suture of this specimen see Pl. XXXII, figs. 4a, 4b, 4c. From basal part of Lake Creek shale member, Pierre formation, W. sec. 7, T. 12 S., R. 38 W., Wallace county, Kansas.

PLATE XXVIII

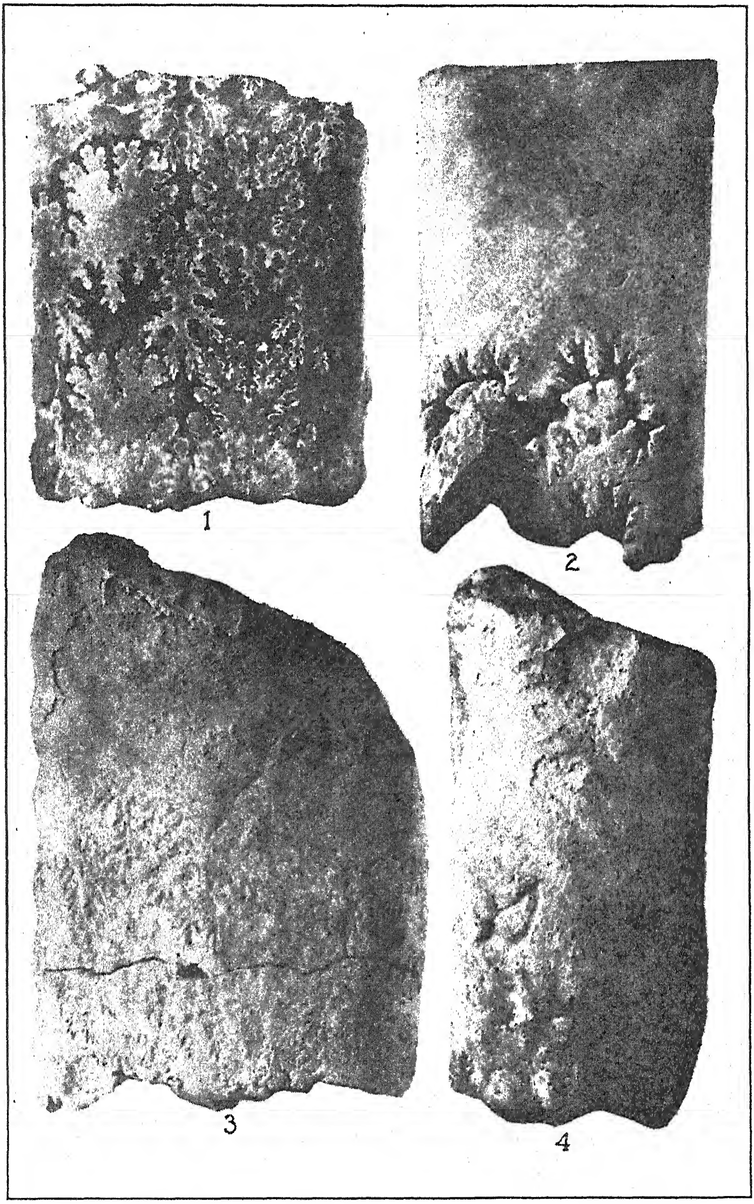


PLATE XXIX

FIGS. 1a, 1b. *Baculites pseudovatus* Elias, n. sp. Cotype. Reduced to 4/5. From upper Weskan shale member, Pierre formation, NW¼ sec. 18, T. 13 S., R. 41 W., Wallace county, Kansas. 1a, side view; 1b, siphonal view. For cross section of this specimen see Pl. XXXIII, fig. 4b.

FIG. 2. *Baculites pseudovatus* Elias, n. sp. Cotype. Natural size. From same locality. For suture and cross section of this specimen see Pl. XXXIII, figs. 4a, 4b.

FIG. 3. cf. *Discoscaphites constrictus* var. *tenuistriatus* (Kner). Natural size. From upper half of Lake Creek shale member, Pierre formation, NE¼ NE¼ sec. 8, T. 11 S., R. 38 W., Wallace county, Kansas.

PLATE XXIX

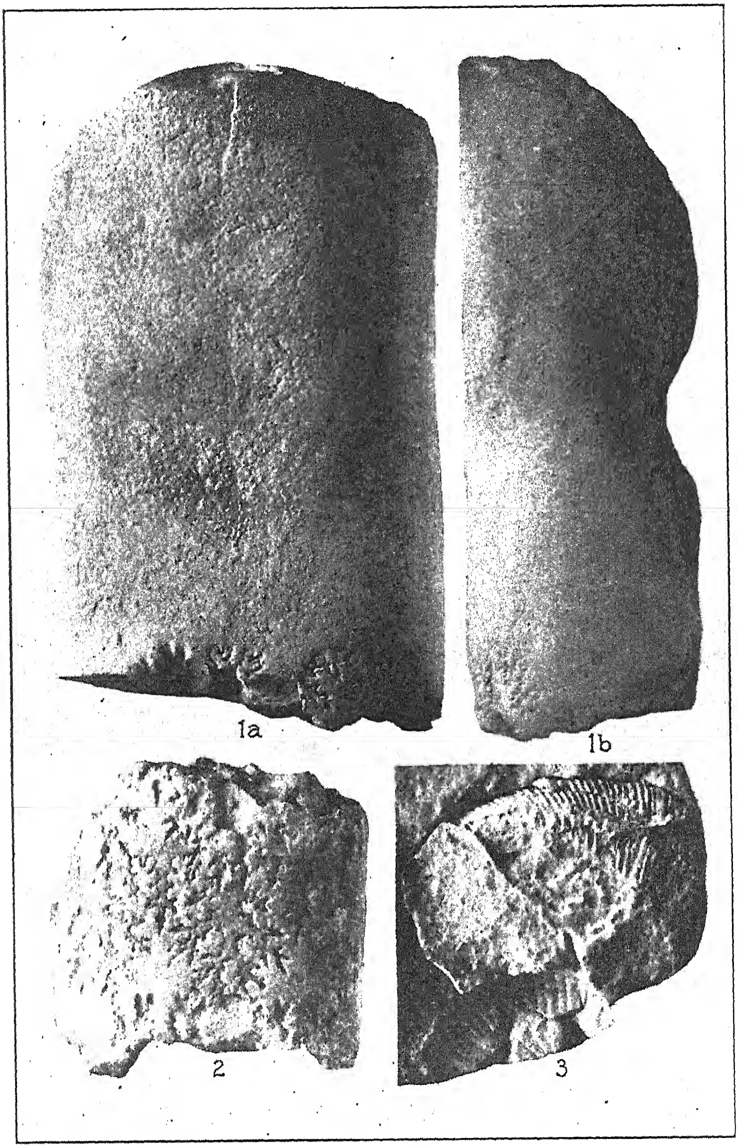


PLATE XXX

FIG. 1. *Baculites clinolobatus* Elias, n. sp. Cotype. Side view. Reduced 2/5. For suture and cross section of this specimen see Pl. XXXIV, figs. 2a, 2b. From Beecher Island shale member, Pierre formation, one-half mile northeast of Beecher Island, Yuma county, Colorado.

FIG. 2. *Baculites clinolobatus* Elias, n. sp. Cotype. Side view. Reduced 2/5. The fragment represents younger stage of the species. Found close to the specimen illustrated on figure 1.

FIG. 3. *Baculites compressus* var. *corrugatus* Elias, n. var. Side of non-septate portion of a large individual. Reduced 1/2. From upper part of Lake Creek shale member, Pierre formation, NW1/4 SW1/4 sec. 5, T. 13 S., R. 41 W., Wallace county, Kansas.

FIGS. 4a, 4b. *Baculites meeki,* n. sp. Holotype. Natural size. From Beecher Island shale member, Pierre formation, 2 miles northwest of Beecher Island, Yuma county, Colorado. 4a, side view; 4b, cross section.

PLATE XXX

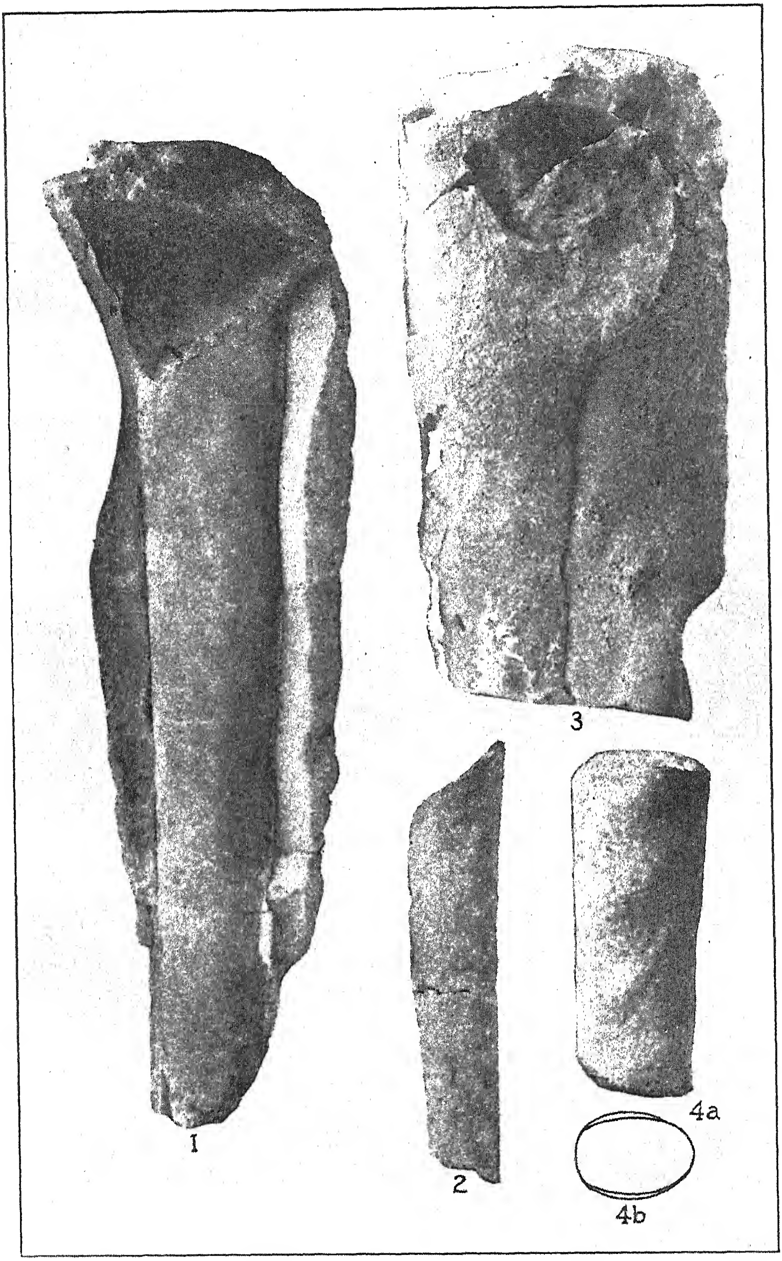


PLATE XXXI

FIGS. 1a, 1b. *Baculites grandis* Hall and Meek. Reduced 1/3. From Beecher Island shale member, Pierre formation, 1 mile northwest of Beecher Island, Yuma county, Colorado. 1a, side view; 1b, siphonal view.

FIGS. 2a, 2b. *Baculites grandis,* Hall and Meek. Reduced 1/3. From Beecher Island shale member, Pierre formation, Hackberry creek, Cheyenne county, Kansas. 2a, side view; 2b, antisiphonal view. For sutures and cross section of this specimen see Pl. XXXIV, figs. 5a, 5b, 5c.

FIG. 3. *Baculites compressus* cf. var. *reesidei* Elias, n. var. Reduced 4/5. Side view. From Lake Creek shale member, Pierre formation, center sec. 35, T. 11 S., R. 39 W., Wallace county, Kansas.

PLATE XXXI

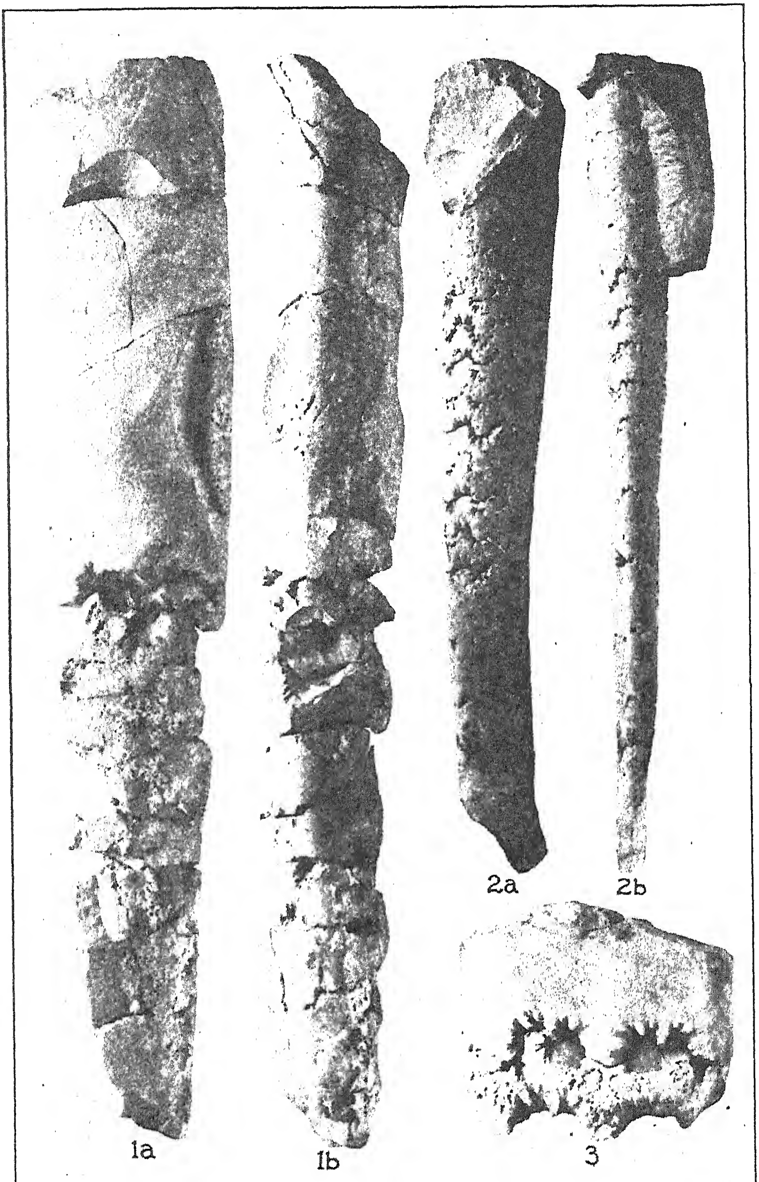


PLATE XXXII

FIGS. 1a, 1b, 1c. *Baculites compressus* var. *corrugatus* Elias, n. var. Holotype. Natural size. From Lake Creek shale member, Pierre formation, SE¼ sec. 29, T. 11 S., R. 39 W., Wallace county, Kansas. 1a, sutures; 1b, siphonal margin; 1c, cross section.

FIGS. 2a, 2b, 2c. *Baculites compressus* var. *reesidei* Elias, n. var. Type. Natural size. From Eagle sandstone in sec. 34, T. 16 N., R. 28 E., Fergus county, Montana. After J. B. Reeside, 1927, Pl. 9, figs. 1, 5. 2a, suture; 2b, siphonal margin (modified after Reeside's photograph); 2c, cross sections.

FIGS. 3a, 3b. *Baculites compressus* Say (in restricted sense). From Pierre formation in Upper Missouri exposures. After F. B. Meek, 1876, Pl. 20, figs. 30a, 30c. Suture reduced by the writer to suit the cross section, which is natural size.

FIGS. 4a, 4b, 4c. *Baculites compressus* Say (in restricted sense). Natural size. From basal part of Lake Creek shale member, Pierre formation, W. sec. 7, T. 12 S., R. 38 W., Wallace county, Kansas. 4a, suture; 4b, siphonal margin; 4c, cross section.

FIGS. 5a, 5b. *Baculites compressus* Say (in restricted sense). Natural size. From upper part of Lake Creek shale member, Pierre formation, in NW¼ SW¼ sec. 5, T. 13 S., R. 41 W., Wallace county, Kansas. 5a, suture; 5b, cross section.

PLATE XXXII

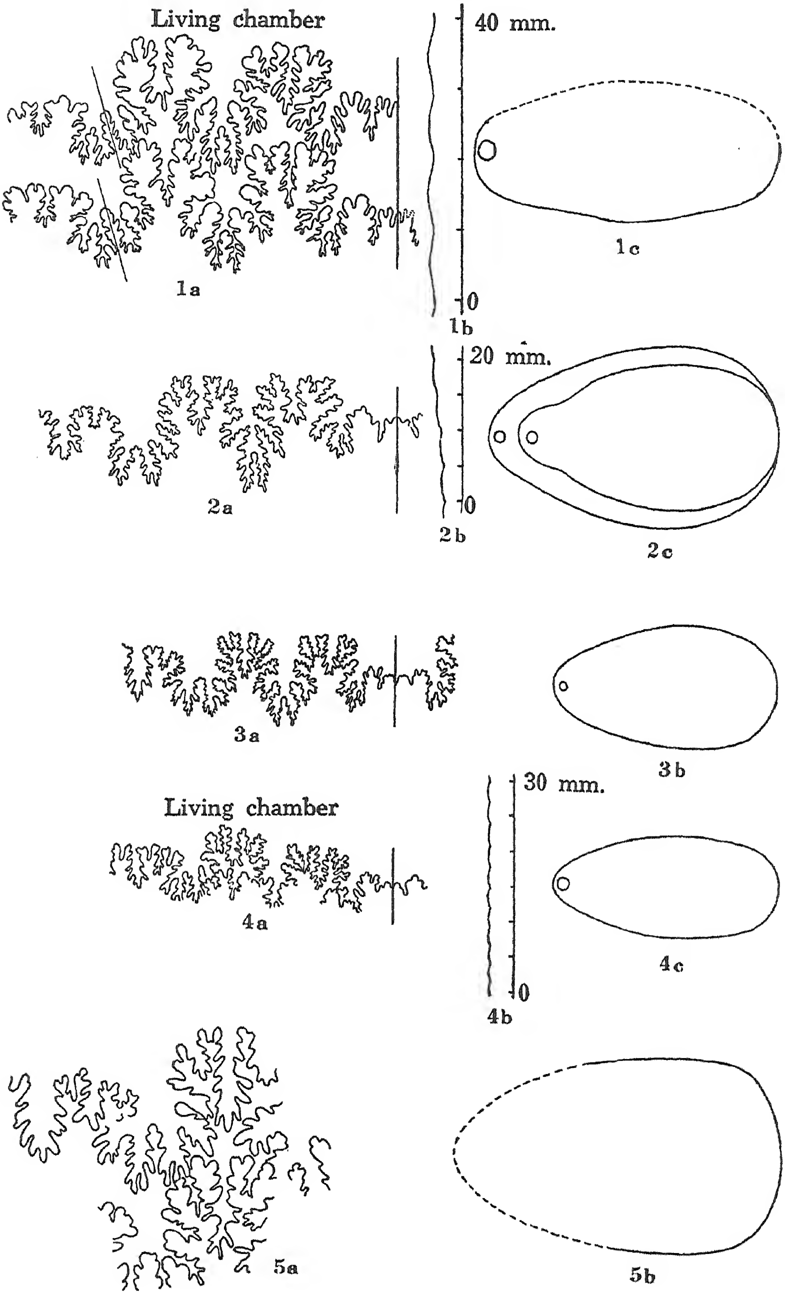

Living chamber
40 mm.
0
1a
1b
1c
20 mm.
0
2a
2b
2c
3a
3b
Living chamber
30 mm.
0
4a
4b
4c
5a
5b

PLATE XXXIII

FIGS. 1a, 1b. *Baculites compressus* cf. var. *reesidei* Elias, n. var. Natural size. From Lake Creek shale member, Pierre formation, center sec. 35, T. 11 S., R. 39 W., Wallace county, Kansas. 1a, suture; 1b, cross section.

FIGS. 2a, 2b, 2c. *Baculites compressus* var. *reesidei* Elias, n. var. Natural size. From Lake Creek shale member, Pierre formation, center sec. 35, T. 11 S., R. 39 W., Wallace county, Kansas. 2a, sutures; 2b, siphonal margin; 2c, cross section.

FIGS. 3a, 3b, 3c. *Baculites ovatus* Say. Natural size. 3a, 3b from Eagle sandstone, near top, in sec. 34, T. 16 N., R. 28 E., Fergus county, Montana. 3c from Elk Basin sandstone member of Telegraph Creek formation in T. 57 N., R. 98 W., Park county, Wyoming. After J. B. Reeside, 1927, Pl. 7, figs. 3, 5, and Pl. 6, fig. 3.

FIGS. 4a, 4b. *Baculites pseudovatus* Elias, n. sp. Cotypes. Natural size. From upper Weskan shale member, Pierre formation, NW¼ sec. 18, T. 13 S., R. 41 W., Wallace county, Kansas. 4a, suture; 4b, cross sections of two specimens.

FIGS. 5a, 5b. *Baculites pseudovatus* var. A Elias, n. var. Holotype. From Baculites zone of Salt Grass shale member, Pierre formation, E. sec. 2, T. 12 S. R. 42 W., Wallace county, Kansas. 5a, suture; 5b, cross section.

PLATE XXXIII

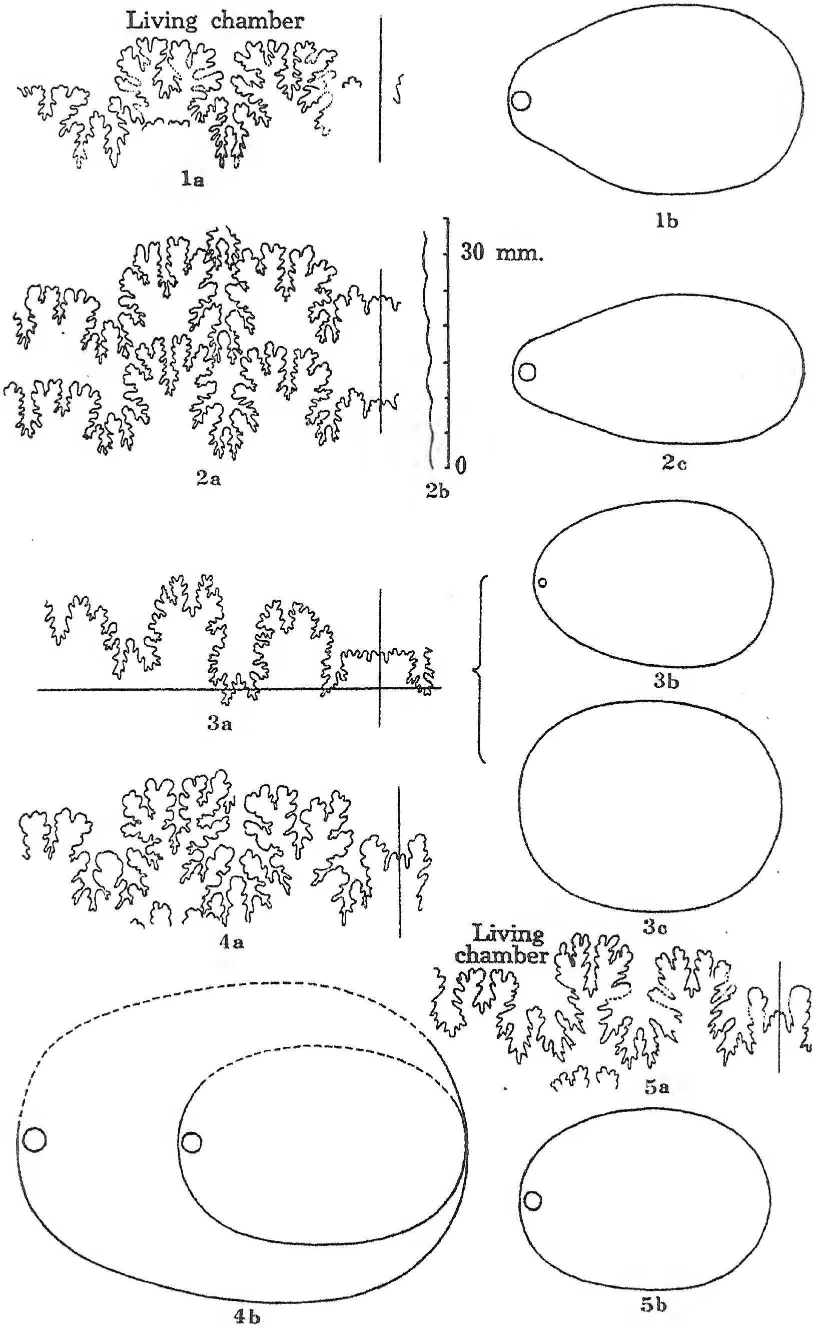


PLATE XXXIV

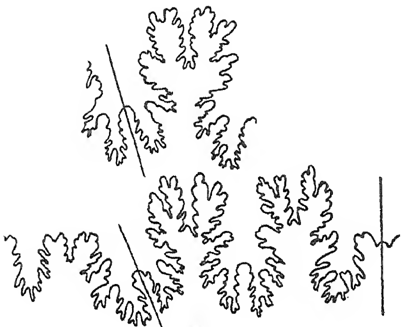
FIGS. 1, 2a, 2b. *Baculites clinolobatus* Elias, n. sp. Cotypes. Natural size. From Beecher Island shale member, Pierre formation, one-half mile northeast of Beecher Island, Yuma county, Colorado. 1, sutures; 2a, sutures of another specimen; 2b, cross sections of the latter.

FIG. 3. *Baculites anceps* var. *leopoliensis* Novak. Natural size. Suture after Novak, 1908, p. 331, fig. 10.

FIG. 4. *Baculites grandis* Hall and Meek. Suture of large individual. Natural size. From Beecher Island shale member, Pierre formation, one-half mile northeast of Beecher Island, Yuma county, Colorado.

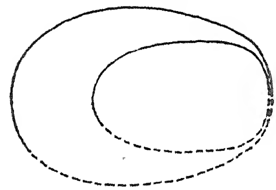
FIGS. 5a, 5b, 5c. *Baculites grandis* Hall and Meek. Natural size. From Beecher Island shale member, Pierre formation, Hackberry creek, Cheyenne county, Kansas. 5a, 5b, sutures of younger stages of the shell; 5c, cross sections of various stages of growth of the shell. Note: The larger cross section belongs to the specimen illustrated on Pl. XXXI, figs. 1a, 1b.

PLATE XXXIV

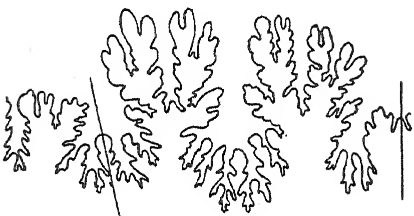


1

2a

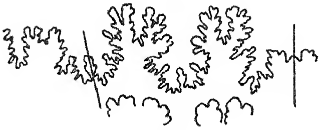


2b



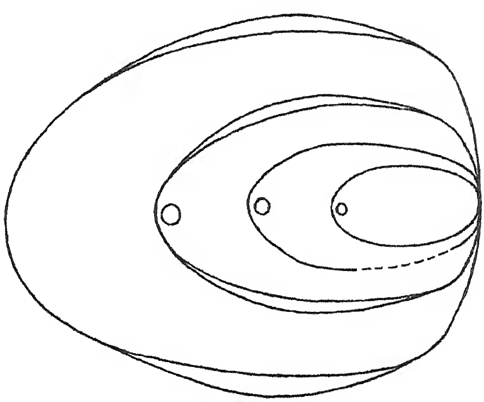
3

4



5 a

5 b



5c

PLATE XXXV

FIGS. 1a, 1b. *Baculites* cf. *pseudovatus* Elias, n. sp. Natural size. From Baculites zone, Salt Grass shale member, Pierre formation, SW¼ sec. 6, T. 13 S., R. 41 W., Wallace county, Kansas. 1a, sutures; 1b, cross section.

FIGS. 2a, 2b. *Baculites compressus* cf. var. *reesidei,* Elias, n. var. Natural size. From basal part of Salt Grass shale member, Pierre formation, NW¼ NE¼ sec. 3, T. 12 S., R. 42 W., Wallace county, Kansas.

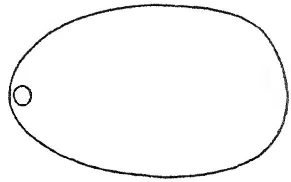
FIGS. 3a, 3b. *Baculites ovatus* var. *haresi* Reeside. Natural size. From Cody shale, 250 feet below top, in NE¼ SW¼ sec. 5, T. 50 N., R. 92 W., Big Horn county, Wyoming. After J. B. Reeside, 1927, Pl. 6, figs. 9, 10.

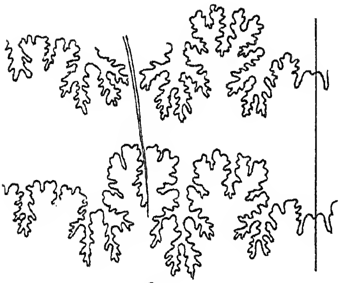
FIGS. 4a, 4b. *Baculites ovatus* var. *haresi* Reeside. Natural size. From basal part of Lake Creek shale member, Pierre formation, S. sec. 15, T. 12 S, R. 38 W., Wallace county, Kansas. 4a, suture; 4b, cross section.

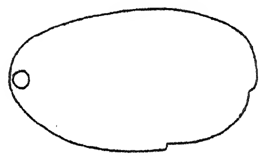
FIGS. 5a, 5b, 5c, 5d, 5e. *Baculites compressus* cf. var. *corrugatus* Elias, n. var. Different stages of growth of a young shell. From basal part of Salt Grass shale member, Pierre formation, NW¼ NE¼ sec. 3, T. 12 S., R. 42 W., Wallace county, Kansas. 5a, cross sections, natural size. 5b, 5c, sutures, natural size; 5d, 5e, sutures, magnified 3 times. Note: The four sutures correspond to the four cross sections of figure 5a.

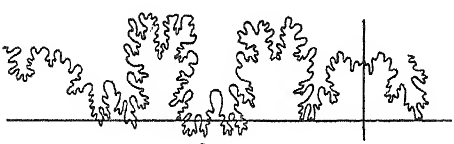
PLATE XXXV

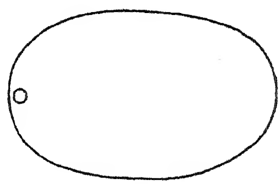

1a


1b


2a


2b


3a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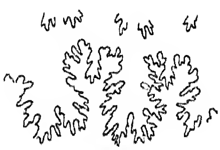
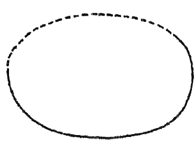
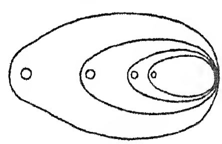
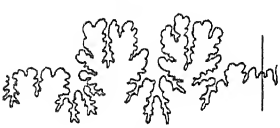
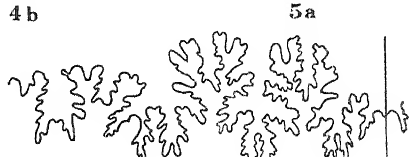

4a


4b


5a


5b


5d


5c


5e

PLATE XXXVI

FIGS. 1a, 1b, 1c. *Scaphites plenus* Meek. Front, side and rear views. Natural size. From Pierre formation of Black Hills.

FIGS. 2a, 2b, 2c. *Scaphites plenus* Meek. Rear, side and front views. Natural size. From basal part of Salt Grass shale member, SW¼ SW¼ sec. 16, T. 13 S., R. 41 W., Wallace county, Kansas.

FIGS. 3a, 3b, 3c. *Discoscaphites nicolleti* var. *saltgrassensis* Elias, n. var. Front, rear and side views. Very slightly enlarged. From basal part of Salt Grass shale member, SE¼ sec. 2, T. 12 S., R. 42 W., Wallace county, Kansas.

PLATE XXXVI

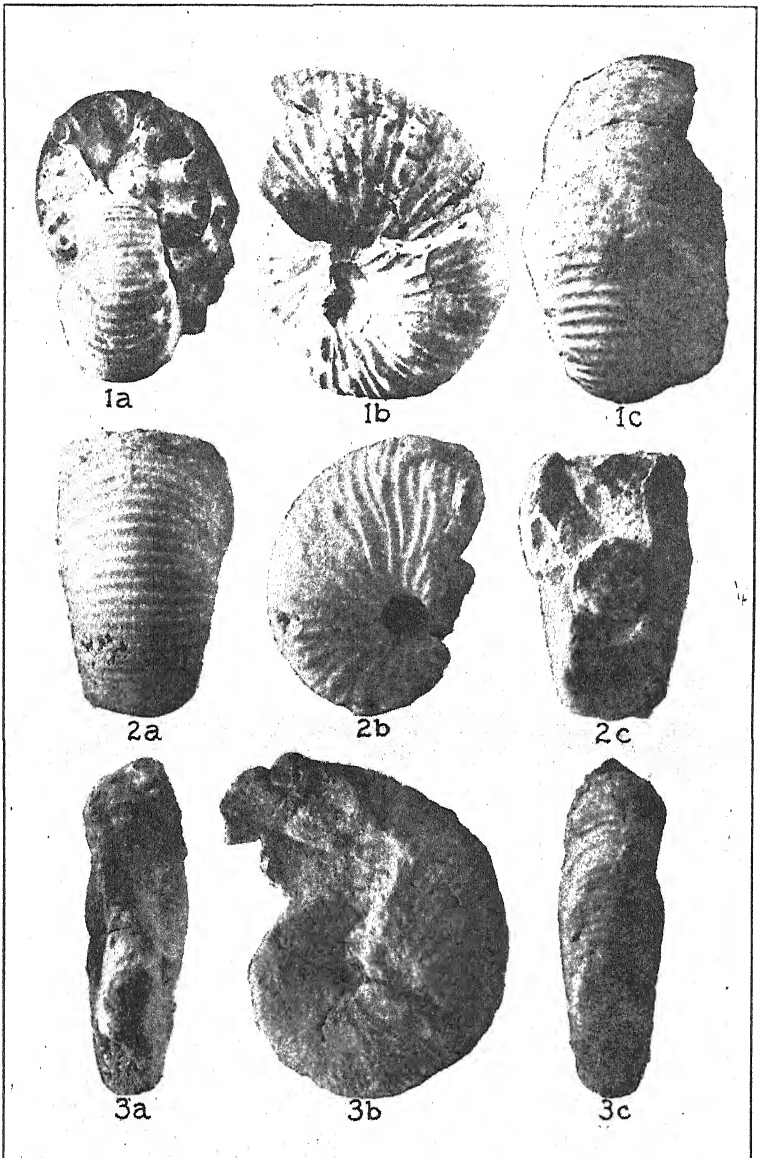


PLATE XXXVII

Figs. 1a, 1b, 1c. *Scaphites plenus* Meek. Back, side and front views. Natural size. From Pierre shale of western South Dakota.

Fig. 2. *Acanthoscaphites nodosus* var. *brevis* Meek. Imperfect specimen in rock. From basal part of Lake Creek shale member, Pierre formation, NW¼ NE¼ sec. 8, T. 13 S., R. 41 W., Wallace county, Kansas.

Fig. 3. *Acanthoscaphites nodosus* var. *quadrangularis*. Fragment of an adult shell. Natural size. Upper part of Lake Creek shale member, sec. 12, T. 12 S., R. 39 W., Wallace county, Kansas.

PLATE XXXVII

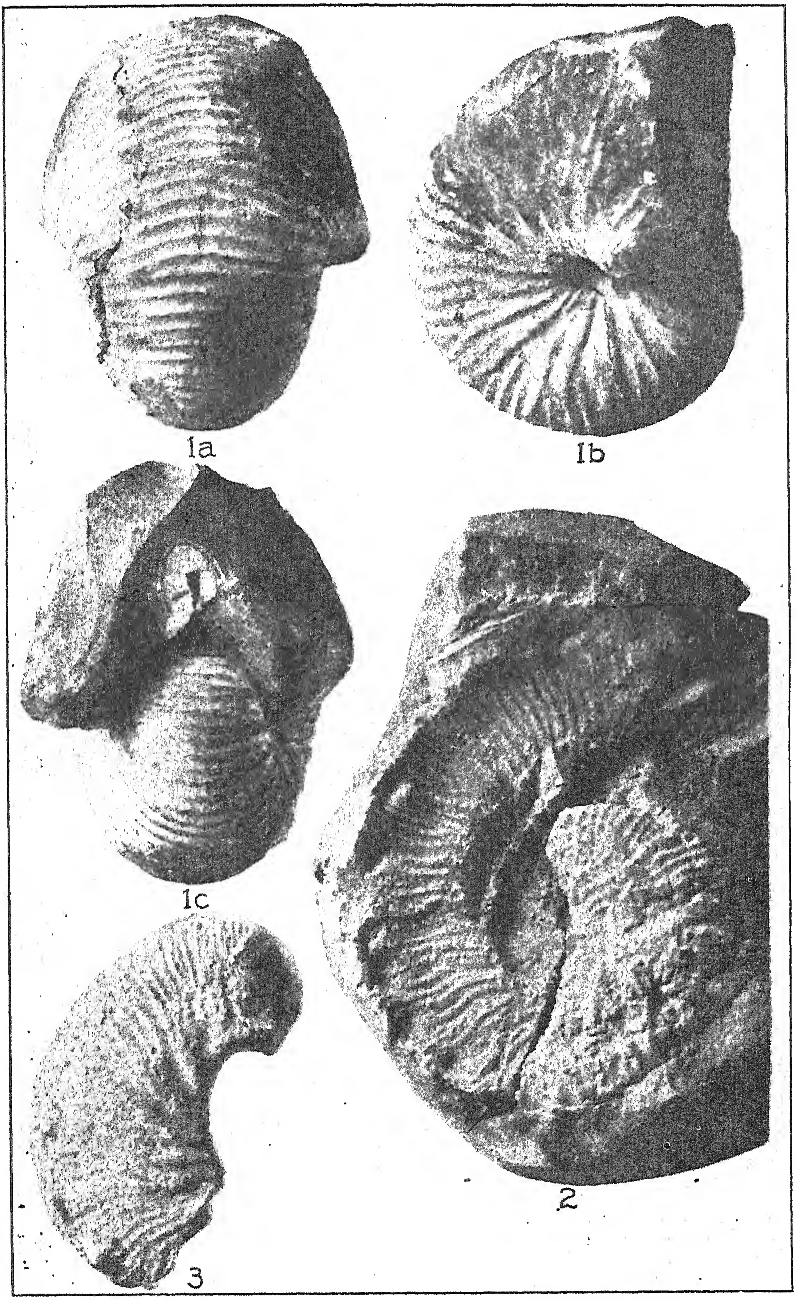


PLATE XXXVIII

FIGS. 1a, 1b, 2. *Acanthoscaphites nodosus* Say (in restricted sense). Slightly reduced. From upper part of Upper Weskan shale member, Pierre formation, NE¼ sec. 8, T. 13 S., R. 41 W., Wallace county, Kansas. 1a, side view; 1b, rear view; 2, side of internal volution of the same specimen.

FIG. 3. *Acanthoscaphites nodosus* Say (in restricted sense). Slightly reduced. From middle part of Lake Creek shale member, Pierre formation, N. sec. 13, T. 13 S., R. 41 W.

PLATE XXXVIII

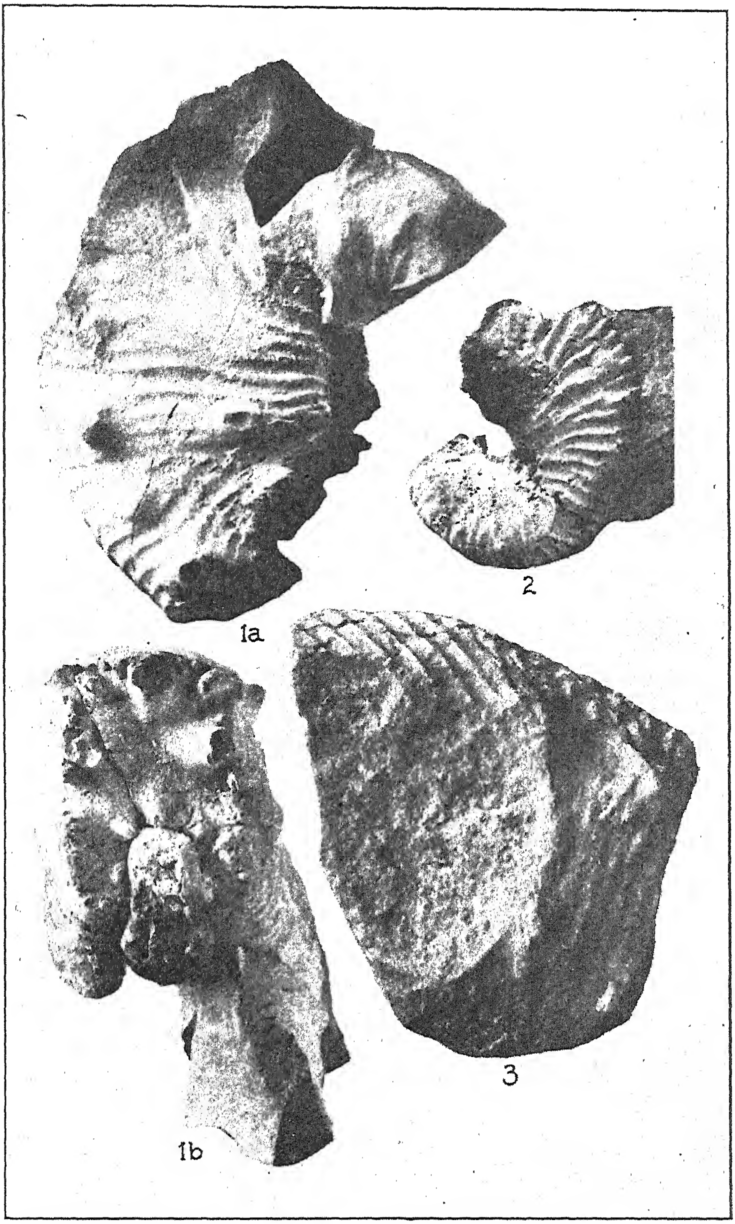


PLATE XXXIX

FIGS. 1a, 1b, 1c. *Scaphites plenus* Meek. Internal volution of the specimen illustrated on Pl. X, figs. 1a, 1b, 1c. Magnified 4/3.

FIGS. 2-5, 6a, 6b, 7, 8. *Discoscaphites abyssinus* (Morton). Natural size, except fig. 5, which is magnified 2 times. From Beecher Island shale member, Pierre formation. 2, 3, 5, 7, 8, from 2 miles northwest of Beecher Island, Yuma county, Colorado. 4, from NE¼ sec. 9, T. 2 S., R. 42 W., Cheyenne county, Kansas. 6a, 6b, from NE¼ sec. 5, T. 1 S., R. 39 W., Cheyenne county, Kansas.

FIGS. 9a, 9b. *Discoscaphites conradi* cf. var. *gulosus* (Morton). From Beecher Island shale member, Pierre formation, 2 miles northwest of Beecher Island, Yuma county, Colorado.

FIG. 10. *Discoscaphites* cf. *constrictus* var. *tenuistriatus* (Kner). Natural size. From Upper Weskan shale member, Pierre formation, center sec. 18, T. 13 S., R. 40 W., Wallace county, Kansas.

PLATE XXXIX

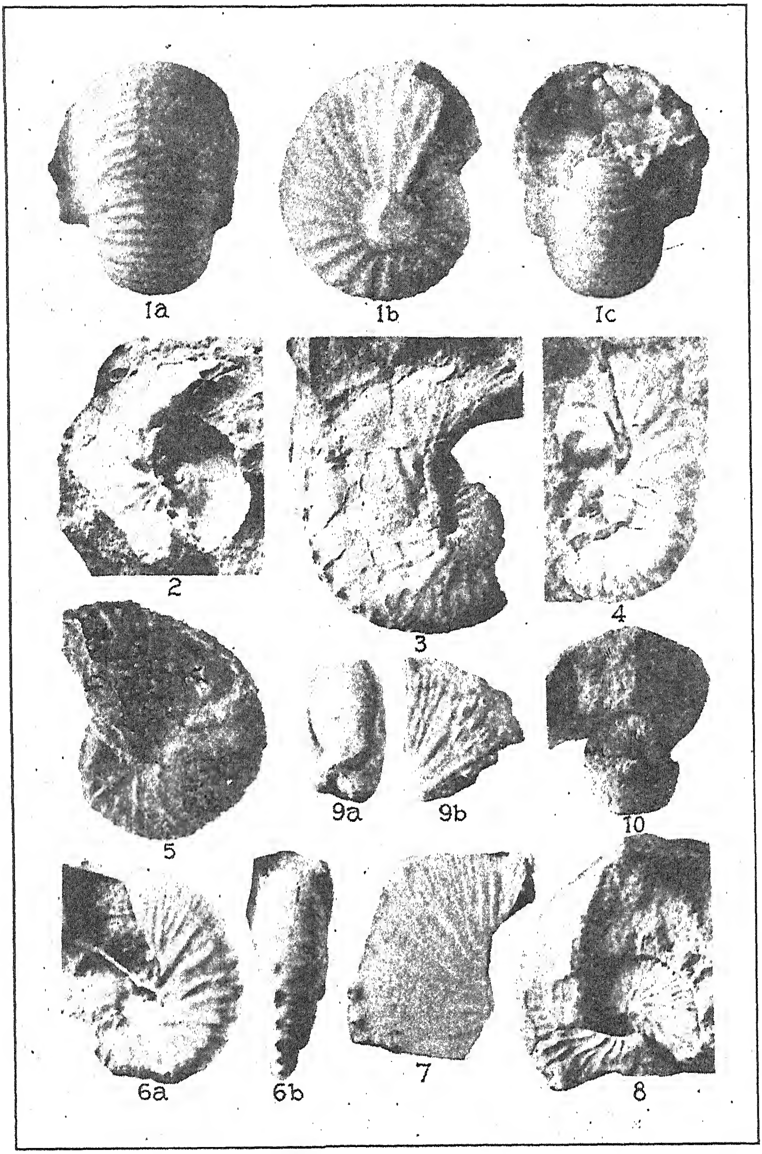


PLATE XL

FIG. 1. *Discoscaphites nicolleti* var. *saltgrassensis* Elias, n. var. Suture of the specimen illustrated on Pl. XXXVI, figs. 3a, 3b, 3c. Magnified 3 times.

FIG. 2. *Discoscaphites abyssinus* Morton. Suture of the specimen illustrated on Pl. XXXIX, fig. 5. Magnified 2 times.

FIG. 3. *Scaphites plenus* Meek. Suture of the specimen illustrated on Pl. XXXVI, figs. 1a, 1b, 1c. Slightly reduced.

FIG. 4. *Scaphites plenus* Meek. Suture of the specimen illustrated on Pl. XXXVII, figs. 1a, 1b, 1c. Slightly reduced.

FIG. 5. *Scaphites plenus* Meek. Suture of the specimen illustrated on Pl. XXXVI, figs. 2a, 2b, 2c. Magnified 3 times.

FIG. 6. *Scaphites plenus* Meek. Suture of the holotype after Meek. Probably somewhat magnified.

FIG. 7. Schematic sketch of a suture of *Baculites compressus* and allied species. SL, Siphonal lobe; 1L, 1st lateral lobe; 2L, 2d lateral lobe; AL, antisiphonal lobe; SS, siphonal saddle; 1S, 1st lateral saddle; 2S, 2d lateral saddle; 3S, 3d lateral saddle; a, stemlike body supporting the terminal branches of the 1st lateral lobe; b, median saddle of the siphonal saddle.

PLATE XL

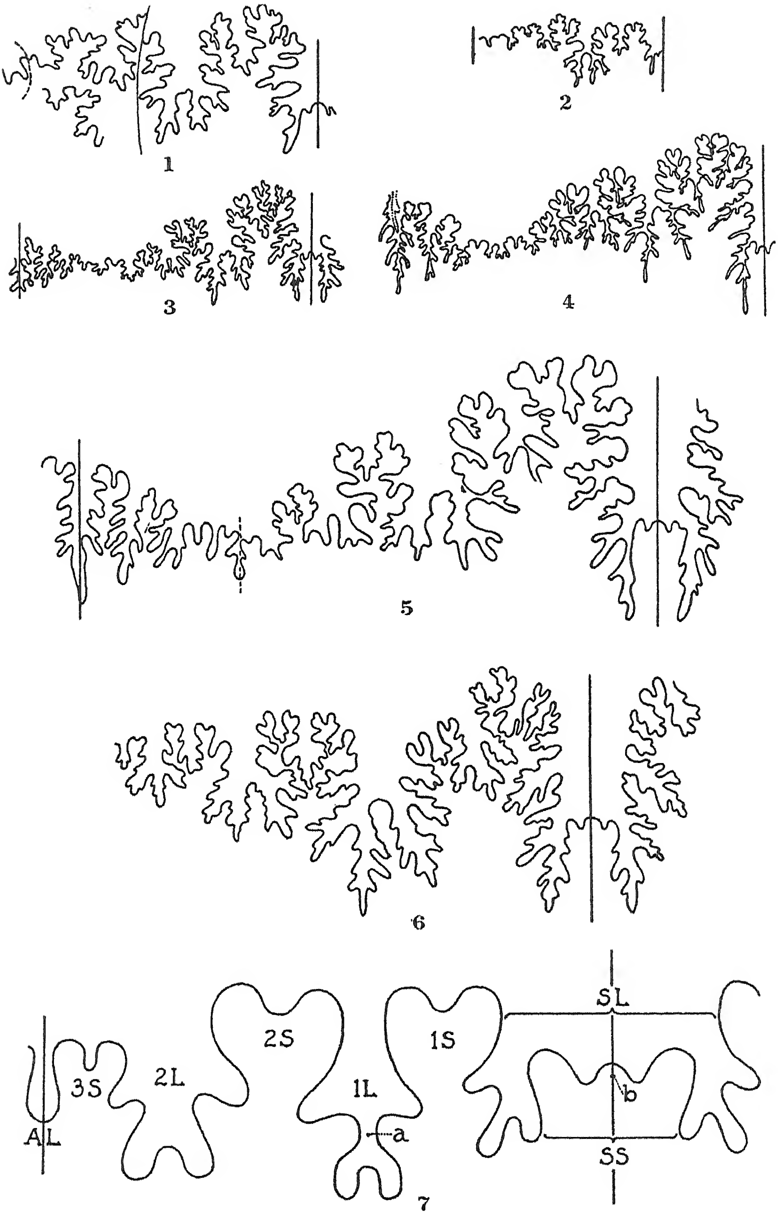


PLATE XLI

FIGS. 1a, 1b, 2. *Placenticeras meeki* Boehm. Reduced 5/12. From basal part of Upper Weskan shale member, Pierre formation, SW¼ NW¼ sec. 18, T. 13 S., R. 41 W., Wallace county, Kansas. 1a, 1b, side and dorsal veiws of septate volution. 2, side view of inner volution.

FIG. 3. *Acanthoscaphites nodosus* var. *brevis* Meek. Reduced 7/9. Side view. From lower part of Lake Creek shale member, Pierre formation, SE¼ sec. 33, T. 11 S., R. 39 W., Wallace county, Kansas.

PLATE XLI

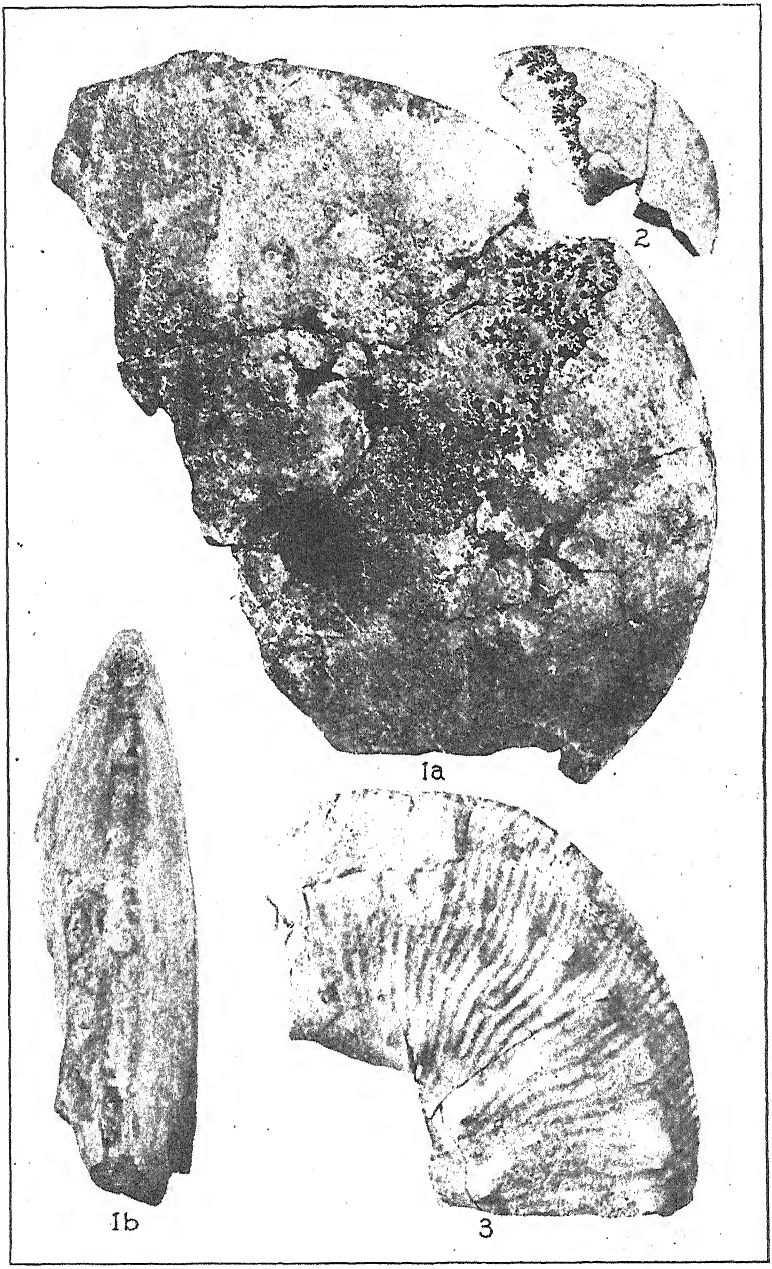
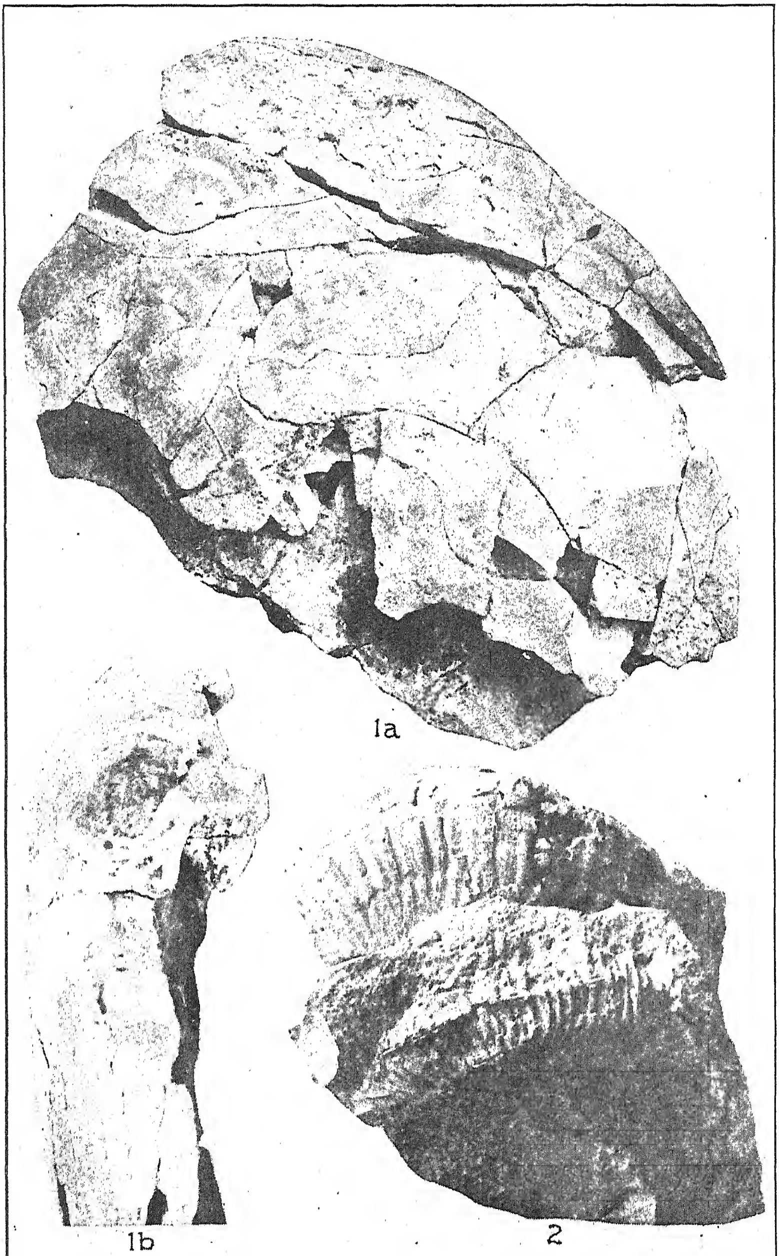


PLATE XLII

FIGS. 1a, 1b. *Placenticeras meeki* Boehm. Part of living chamber which overlaps umbilicus. Reduced ¼. From basal part of Upper Weskan shale member, Pierre formation, SW¼ NW¼ sec. 18, T. 13 S., R. 41 W., Wallace county, Kansas. 1a, side view; 1b, dorsal view. The septate volution of this specimen, which is here overlapped by living chamber, is illustrated on Pl. XLI, figs. 1a, 1b.

FIG. 2. *Heteroceras tortum* Meek and Hayden. Natural size. From top of Sharon Springs shale member, Pierre formation, sec. 2, T. 14 S., R. 40 W., Wallace county, Kansas.

PLATE XLII



THE UNIVERSITY OF KANSAS
SCIENCE BULLETIN

VOL. XXI.] MARCH, 1933. [No. 10.

A New Megasecopteron from the Carboniferous of Kansas

By F. M. CARPENTER

ABSTRACT: The order Megasecoptera has previously been represented in the American Carboniferous by only two fragmentary wings of doubtful affinities. A new fossil, *Parabrodia carboniara*, n. sp., found in the Upper Carboniferous of Garnett, Kan., and belonging to a new family, Parabrodiidæ, is a typical member of the order, closely related to the European Brodia. The type is in the Geological Museum of the University of Kansas.

THE Carboniferous members of the extinct order Megasecoptera are known almost exclusively from European deposits. Only two fossils [1] from the North American Carboniferous can be fitted into the order, and both of these are so fragmentary and aberrant that they were placed there only tentatively by Handlirsch. But a new fossil, recently found by M. K. Elias in the Carboniferous of Kansas, consists of a nearly complete wing typical of the European Megasecoptera of this horizon. To Mr. Elias and the authorities of the Geological Department of the University of Kansas I am indebted for the opportunity of studying this insect.

As we might expect from its unique geographical position, the fossil belongs to a new family:

PARABRODIIDÆ, NEW FAMILY

Allied to the family Brodiidæ, from the English Carboniferous (Westphalian), but differing in the possession of a definite coalescence of MA with Rs.

1. *Raphidiopsis diversipenna* Scud., from Rhode Island, and *Prochoroptera calopteryx* Handl., from Mazon creek, Illinois.

PARABRODIA, New Genus

Medium-sized insects; wings slender, probably subpetiolate; Sc extending well beyond the middle of the wing; Rs arising about the middle of the wing, almost immediately coalescing with MA; Rs 2-branched; M free from R at the base of the wing; MA unbranched; MP forked; Cu1 and Cu2 unbranched; Cu1 probably coalescing with M at the base of the wing.

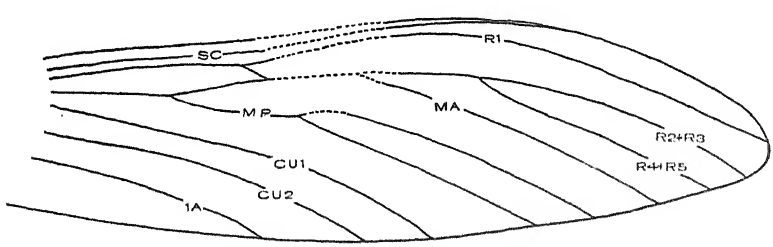
Genotype: *Parabrodia carbonaria* n. sp.

Parabrodia carbonaria n. sp.

(Figure 1)

Length of wing, 24 mm.; width, 7 mm.; apex pointed; Sc straight; R with a slight bend at the origin of Rs; R1 remote from the margin of the wing distally; MA fused with Rs for a distance about as long as its free part proximad of the coalescence; MP diverging apically of the origin of Rs and proximad of the divergence of MA from Rs; Cu1, Cu2, and 1A nearly parallel. No cross veins are preserved.

Holotype. In Geological Museum, University of Kansas; collected by M. K. Elias, six miles northwest of Garnett, Kan.[2] Horizon is the late middle Pennsylvanian.



TEXT FIGURE 1

The wing is preserved on a large slab of light-brown shale, containing remains of Walchia and other plants, one of which overlies a part of the anterior margin. The veins are only faintly preserved, and in making the accompanying figure I have used to advantage an excellent photograph provided by Mr. Elias.

As I have mentioned above, Parabrodia is especially interesting because it is the first typical Megasecopteron to be found in a satisfactory state of preservation in the Carboniferous of North America.

2. The locality is mentioned in the abstract "Conifer Forest of Late Middle Pennsylvania Time," by Mr. Elias, published in the Proceedings of the Paleontological Society: Bull. Geol. Soc. Amer., 43:285; 1932.

The shape of the wing is closest to that of the members of the family Brodiidæ, but in the latter the anterior media (MA) does not quite coalesce with Rs, and the radial sector (Rs) has five branches. If my interpretation of the formation of Rs, i. e., its division into R2 + 3 and R4 + 5, is correct, then the structure of the vein approaches that of Raphidiopsis and the Permian Protohymenoptera. But, unfortunately, the convexity and concavity of the veins are not preserved, and it is possible that the vein which I have named MA really consists of a compound vein formed by the fusion of MA and R4 + 5, and that the independent branches of Rs are R2 and R3. In either case the venation as a whole could easily be derived from that of the Brodiidæ or some closely related family.

THE UNIVERSITY OF KANSAS
SCIENCE BULLETIN

VOL. XXI.] MARCH, 1933. [No. 11.

Comparative Anatomical Research Within the Genus *Ribes* *

JAMES C. BATES

ABSTRACT: The results obtained from a detailed anatomical and histological study of fifteen species of *Ribes* are summarized and some conclusions drawn as to their probable genealogical relationships.

The species showed considerable differences in the following features: Amount and distribution of trichomes of the leaf epidermis; absence or presence of glands and kinds of glands; shape of leaf epidermal cells; shape of leaf tip; margin and midrib; number of layers of palisade cells; number of vascular bundles entering the petiole; presence or absence of trichomes of the stem epidermis; presence or absence of bast fibers in the petiole; stem armed or unarmed; shape and size of stem epidermal cells; cutinization of radial walls of stem epidermal cells; kinds of collenchyma; number of rings of peridermal tissue in the two years' growth; number of protoxylem points; length of xylem elements; and the distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the stem and leaf.

Suggestions as to the genealogical relationships of the fifteen species are based on their similarities and differences in anatomical structure and cell contents. Some of the highest degrees of anatomical relationship found were between American and European species, and some of the lowest between some American species and between American and European species.

The paper includes 8 tables, five plates and 1 figure.

INTRODUCTION

THE writer has attempted to summarize the results obtained from a detailed anatomical study of the following fifteen species of *Ribes,* and to offer a few suggestions as to their probable genealogical relationships: *R. aureum* Pursh., *R. alpinum* L., *R. americanum* Mill., *R. cynobasti* L., *R. diacantha* Pall., *R. fasciculatum* Sieb. & Zucc., *R. hirtellum* Michx., *R. holosericeum* Otto &

* This work was carried out in the Botany Department of the University of Kansas under the direction of Prof. W. C. Stevens. The writer desires to make his appreciative acknowledgment to Professor Stevens for his help and encouragement during the preparation of the work here presented.

Dietr., *R. luridum* Hook. f. & Thoms., *R. missouriense* Nutt., *R. Nigrum* L., *R. sativum* Syme., *R. stenocarpum* Maxim., *R. tenue* Jancz., and *R. vilmorinii* Jancz.

These species, brought together from their native places in different parts of the earth, were growing in the Arnold Arboretum, Boston, and the differences which they show are therefore inherent and not due to the influence of different environments. This is considered a vital fact for this research.

SUMMARY OF PUBLISHED ANATOMICAL RESEARCH

A comparatively small amount of anatomical work on *Ribes* has been published by Petit, Reinke, and Holle, and summarized by Solereder (1908) in his "Systematic Anatomy of the Dicotyledons," Vol. I.

According to Holle (1893) the cuticle is thin in all species of *Ribes* examined. The hairs are long, simple, and conically pointed.

Solereder claims the unicellular trichomes are not calcified and that external glands have been observed only on the leaves of the genus. The glandular trichomes on the leaf and stipules of *Ribes,* according to Solereder, are shaggy hairs with a multiseriate stalk of variable length and a spherical or peltate head, the center of which is occupied by isodiametric cells, while the epidermal cells are elongated radially like a palisade.

According to Holle the glandular hairs differ in various species and are divided by him into two classes: (*a*) Wedge-formed glandular hairs with a rounded multicellular head and a rather long, several-celled stalk. In this group he includes *R. alpinum, R. aureum, R. cynobasti,* and *R. fasciculatum.* (*b*) Sessile glands with a relatively large multicellular head on a short multicellular stalk submerged in the epidermis. In this group he includes *R. americanum* and *R. nigrum.*

The spines of the species of *Ribes* are, according to Delbrouck (1875), essentially periblem structures.

Occasionally the leaf-teeth in species of *Ribes* have a glandular function, according to Reinke (1876).

Holle (1893) attributes the following features to *Ribes*: Epidermal cells with mostly straight side walls, as seen in surface view; the possession of fairly small pairs of guard cells of nearly circular outline and always surrounded by many associate cells; from one to three layers of palisade cells; the larger vascular bundles in the leaf with mostly thin-walled strengthening tissue extending to the

epidermis of both surfaces; and isolated sclerenchyma fibers entirely lacking in both leaf and stem.

According to Petit (1887), all investigated species of *Ribes* have three vascular bundles pass into the petiole.

The following account of conditions found in the cortex, phloëm and xylem are given by Holle.

CORTEX. The two to three outer layers of the primary cortex are thickened collenchymatously, the walls of the outer layer becoming thickened all around. Aside from collenchyma this genus is lacking in all sclerotic elements in both primary and secondary cortex, unless some walls of the cork cells become sclerotic. Very characteristic also are the tangential rings and bands of cells, radially one cell broad, bearing small rosette crystals. Also in the primary cortex and pith of this genus are rosette crystals of considerably larger size. The contents of the cortical parenchyma cells are often brown in color and possessed of tannin, especially in the outer cortex layers of *Ribes*. Cork originates in the innermost part of the cortex, and the cork cells are somewhat radially elongated.

PHLOËM. In the phloëm are one to four regular transverse rows of contiguous, small cluster crystals, the number of rows being characteristic of the species.

XYLEM. The medullary rays reach as high as seven cells in breadth. The elements of the tracheal tubes have in the end walls scalariform perforations with few thick strips. The wall of a vessel where it is in contact with the parenchyma of the medullary rays bears bordered pits only. The wood prosenchyma, which mostly has thick walls, bears bordered and simple pits. The lumen of the simple-pitted wood fibers in *Ribes* is septate.

Holle (1893) divides the species into two classes and gives some of their distinguishing characteristics as follows:

(*a*) WITH STALKED GLANDULAR HAIRS. *R. alpinum* L. (Furstenstein, ex Herb. G. A. Pritzel.) Epidermal cells with undulating side walls. Palisade tissue one-rowed. Cluster crystals in the palisade tissue. Three to four regular transverse rows of cluster crystals in the phloëm.

R. aureum H. (Hort. Botan. Monac.) Upper epidermal cells with straight side walls, somewhat bulging outward. Palisade tissue two- to three-rowed. Cluster crystals few in the leaf. An almost continuous row of cluster crystals in the phloëm, and outside this are sometimes groups of a second row.

R. cynobasti L. (Ohio; Doctor Frank.) Epidermal cell with un-

dulating side walls. Palisade tissue one rowed. Only one, often interrupted, regular transverse row of cluster crystals in the phloëm.

R. fasciculatum S. et Z. Leg. (Burger, Japan.) Four to five almost continuous rows of cluster crystals in the phloëm.

(*b*) WITH SESSILE GLANDULAR HAIRS. *R. americanum* Mill. (Americ. Septentr, Ehrhard, Select. 14.) Epidermal cells with undulated side walls. Stomata oval. Only the larger vascular bundles are extended from surface to surface by weak strengthening tissues. Palisade tissue in one row. Spongy parenchyma compact. One to two almost uninterrupted rows of small cluster crystals in the phloëm.

R. nigrum L. (In Silva Caspat. Comm., Kitaibel.) This is distinguished from *R. multiflorum* in that only isolated groups make up the two rows of cluster crystals in the phloëm.

SUMMARIZED DISCUSSION OF MICROCHEMICAL TESTS IN STEMS, PETIOLES AND MIDRIBS

The distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the stem, petiole, midrib and blade are given in Tables I, II and III. These substances are represented by the symbols s, t and *, respectively, and their relative abundance is shown by the number of symbols occurring together. Thus: "s" represents a small amount of starch, "ss" a moderate amount, and "sss" an abundance of starch. The figures in the third column of Table I indicate the number of transverse rows of cluster crystals of calcium oxalate in the phloëm.

TABLE I.—Showing the distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the stem.

	Phello-derm.	Inner Cortex.	Phloëm.	Xylem rays.	Xylem Par.	Pith.
R. holosericeum	sss tt	sss tt *	sss tt *2–3	s tt	....	sss tt *
R. tenue	ss ttt	.... ttt	ss ttt	.... tt	....	ss ttt
R. aureum	sss ttt	ss ttt *	ss ttt *1–2	ss ttt	s	sss ttt *
R. diacantha	sss ttt	ss ttt	ss ttt	ss ttt	....	sss ttt
R. americanum	sss ttt	sss ttt **	sss ttt *1–2	sss ttt	....	sss ttt **
R. nigrum	sss ttt	ss ttt **	sss ttt *1–3	sss ttt	....	sss ttt **
R. fasciculatum	sss t	sss t	sss t *4–5	sss t	sss	sss t ....
R. alpinum	sss ttt	sss ttt	sss ttt *3–4	sss ttt	s	sss ttt *
R. sativum	sss ttt	sss ttt *	sss ttt *1–3	.... ttt	....	sss ttt *
R. luridum	s ttt	s ttt	s ttt *1	sss ttt	....	s ttt *
R. stenocarpum	tt	tt **	tt *1–2	t	....	tt **
R. vilmorinii	s ttt	s ttt	s ttt *	s ttt	....	s ttt *
R. missouriense	sss t	sss t **	sss ttt *1–4	ss tt	s	sss tt **
R. cynobasti	s t	.... ttt *	.... ttt *1–2	.... ttt	....	s tt **
R. hirtellum	tt	tt *	t *2–4	t	....	t **

TABLE II.—Showing the distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the petiole.

	Epidermis.	Cortex.	Phloëm.	Xylem.	Bast.
R. holosericeum	tt	tt	tt	tt	....
R. tenue	tt	tt **	tt	t	t ....
R. aureum	.... tt	ss t	s tt	s tt	....
R. diacantha	tt	t	tt	tt	....
R. americanum	.... tt	ss t	ss tt	ss tt	.... t
R. nigrum	.... tt	ss t	ss tt	ss tt	.... t
R. fasciculatum	.... t	ss t	ss t	ss t	.... t
R. alpinum	t	t *	tt	tt	t ....
R. sativum	t	t	t	t	t
R. luridum	tt	tt	tt	tt	tt
R. stenocarpum	t	t	t	t	....
R. vilmorinii	t	t	t	t	....
R. missouriense	tt	tt	tt	tt	tt
R. cynobasti	t	t	tt	tt	tt
R. hirtellum	t	t	tt	tt	....

When tannin and starch are present, they are always found in the phelloderm and pith and nearly always in the inner cortex, phloëm, and phloëm and xylem rays. These two substances are quite uniformly distributed throughout the pith cylinder, with the exception of *R. missouriense*, which has a larger amount of starch in the peripheral pith cells. These two substances, when both present, are usually found occurring together within the cell. A small amount of starch is found in the xylem parenchyma cells of *R. aurem*, *R. alpinum*, *R. missouriense*, and a relatively large amount in *R. fasciculatum*. Cluster crystals of calcium oxalate were found scattered throughout the cortex and pith, and in regular transverse rows in the phloëm of the majority of species studied. Tannin is always present, and starch is found in all species except *R. stenocarpum* and *R. hirtellum*, but varies in amount in the different species. Table III shows that both tannin and starch may be present in abundance; either may be in excess of the other, or tannin may be present in small or moderate amount with starch absent. Thus the different species may be grouped according to their tannin and starch content as follows: (1) Abundance of both tannin and

TABLE III.—Showing the distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the midrib and blade.

	Midrib.				Mesophyll.	
	Epidermis.	Paren-chyma.	Phloem.	Xylēm.	Palisade.	Spongy.
R. holosericeum	tt	tt	tt	tt	tt *	tt
R. tenue	tt	t	tt	tt	tt	tt
R. aureum	.... tt	s tt	s tt	s tt	ss tt	s tt
R. diacantha	tt	....	tt	tt	tt	tt
R. americanum	tt	tt	tt	tt	tt	tt
R. nigrum	tt	tt	tt	tt	tt	tt
R. fasciculatum	.... tt	ss tt	ss tt	ss tt	ss tt	ss tt
R. alpinum	tt	tt	tt	tt	tt	tt
R. sativum	tt	t	tt	tt	tt	tt
R. luridum	t	t	tt	tt	tt	tt
R. stenocarpum	tt	tt	tt	tt	tt	tt
R. vilmorinii	tt	tt	tt	tt	tt	tt
R. missouriense	tt	tt	tt	tt	tt	tt
R. cynobasti	t	t	tt	tt	tt **	tt
R. hirtellum	t	t	tt	tt	tt *	tt ....

starch, *R. aureum, R. diacantha, R. americanum, R. nigrum, R. alpinum,* and *R. sativum;* (2) abundance of tannin and a moderate amount of starch, *R. tenue;* (3) abundance of tannin and a small amount of starch, *R. luridum, R. vilmorinii,* and *R. cynobasti;* (4) moderate amount of tannin and abundance of starch, *R. holosericeum* and *R. missouriense;* (5) small amount of tannin and abundance of starch, *R. fasciculatum;* (6) a small to moderate amount of tannin with starch absent, *R. stenocarpum* and *R. hirtellum.* The distribution of starch and tannin in the petiole and midrib is given in Tables II and III, only two classes of frequency being indicated. Table II shows for the petiole that starch was found only in the cortex, phloëm, and xylem of four species: *R. aureum, R. americanum, R. nigrum,* and *R. fasciculatum.* Tannin is always present in the epidermis, cortex, phloëm, and xylem rays and usually in the bast fibers, the amount varying somewhat in the different species. Relatively small amounts of tannin were found in *R. fasciculatum, R. sativum, R. stenocarpum,* and *R. vilmorinii.* The remaining species contained relatively large amounts of tannin in the phloëm and xylem; however, the amount was small in the epidermis, cortex,

and bast fibers of some species. Cluster crystals of calcium oxalate were found in the cortex of *R. tenue* and *R. alpinum*. Starch was found in the midrib and mesophyll of *R. aureum* and *R. fasciculatum*. All of the tissues of the leaf contained relatively large quantities of tannin. Cluster crystals of calcium oxolate were found in the palisade tissue of *R. holosericeum* and *R. hirtellum*.

Tests were made, also, for sugar, glucosides, protein, volatile oils, resins, calcium carbonate, and mucilage, but only negative results were obtained.

SUMMARY OF STEMS

The following features are common to the stems of all of the fifteen species studied: The outer wall of each epidermal cell is cutinized and projecting. The epidermal cells are elongated vertically, but vary considerably in the amount of elongation in the different species; radial walls are straight and pitted (Plate XLIII, figs. 14-28). The absence of both endodermis and bast fibers. The formation of cork within the innermost part of the cortex, and the sloughing off of the epidermis and outer part of the cortex soon after their formation. A relatively small amount of phloëm consisting of phloëm parenchyma, sieve tubes, and companion cells. Protoxylem points project into the pith cylinder, giving it a stellate appearance as seen in cross section (Plate XLIV). The protoxylem consists of tracheal tubes with spirally thickened walls. The metaxylem is composed of tracheal vessels with bordered pits and a small amount of xylem parenchyma. The secondary xylem has fiber tracheids and wood fibers, in addition to the elements found in the metaxylem, and its elements are radially arranged. Xylem elements from 1-10 rows wide alternate tangentially with xylem rays from 1-7 cells wide. The tracheal vessels have oblique cross walls with few thick strips, reticulate pitting, and scalariform perforations in the end walls of their elements. The xylem rays consist of vertically elongated cells with the vertically longest cells occurring at the upper and lower extremities of the ray. A relatively large cylinder of homogeneous pith. The cells at the center of the cylinder have larger cross diameters and relatively thinner walls than those bordering the xylem. The presence of tannin in the phelloderm, cortex, phloem, xylem rays and pith.

Trichomes are present in 9 of the 15 species studied. Those without trichomes are *R. aureum, R. diacantha, R. alpinum, R. luridum, R. missouriense,* and *R. hirtellum*. There is considerable variation in amount and length of trichomes in the various species (Plate

XLIII, figs. 1-6). *R. holosericeum* and *R. sativum* have a small amount of short trichomes with an average length of .07 mm. *R. vilmorinii, R. americanum,* and *R. tenue* have a moderate amount with an average length of .06, .12, and .20 mm., respectively. The remaining four species have a dense amount with an average length of .04 mm. in *R. nigrum,* and .16 mm. in *R. fasciculatum, R. luridum,* and *R. cynobasti.* The radial walls of the epidermal cells are cutinized in all except the following six species: *R. tenue, R. sativum, R. vilmorinii, R. missouriense, R. cynobasti,* and *R. hirtellum.* Multicellular sessile glands (Plate XLIV, fig. 3) were found with the epidermis of *R. americanum* and *R. nigrum,* and *multicellular* stalked glands with the epidermis of *R. alpinum* and *R. cynobasti.* According to Holle (1893) external glands have been observed on the leaves only of this genus.

There is also considerable variation in the vertical elongation of the epidermal cells, which ranges from very slight in *R. americanum, R. nigrum, R. cynobasti,* and *R. hirtellum* to considerable elongation in *R. fasciculatum, R. sativum,* and *R. missouriense.* Typical collenchyma (Plate XLIV, Fig. 2) was found lignified in *R. stenocarpum, R. missouriense,* and *R. cynobasti.* The cork cells are tangentially elongated in all of the fifteen species except *R. aureum, R. americanum,* and *R. luridum.* According to Solereder (1908) the cork cells are somewhat radially elongated. *R. missouriense* differs from all other species in having three rings of peridermal tissue in the two years' growth. Table IV shows the number of protoxylem points, diameter of pith cylinder, and number of tracheal tubes per square mm. of xylem area in each of the fifteen species studied. The number of protoxylem points varies from 6-16 in the different species. There is also considerable variation in diameter of pith cylinders, which ranges from .43 mm. to 1.92 mm. There is little or no correlation between diameter of pith cylinder and number of protoxylem points. The number of tracheal tubes per square mm. varies from 690 in *R. fasciculatum* and *R. luridum* to 1725 in *R. americanum.* Table V shows the average length of tracheal elements, tracheids, and wood fibers in the different species. The average length of tracheal elements varies from .22 mm. in *R. sativum* and *R. hirtellum* to .46 mm. in *R. holosericeum.* The average length of tracheids shows a similar variation, ranging from .21 mm. in *R. diacantha, R. alpinum,* and *R. cynobasti* to .46 mm. in *R. hirtellum.* The greatest variation occurs in the length of wood fibers, which ranges from .22 mm. in *R. sativum* to .55 mm. in *R. tenue.*

TABLE IV.—Showing the number of protoxylem points, diameter of pith cylinder, and number of tracheal tubes per square mm. of xylem area.

	Number protoxylem points.	Diameter pith cylinder.	Number tracheal tubes.
		mm.	
R. holosericeum	15	1.20	1,480
R. tenue	11	.52	1,380
R. aureum	12	.43	1,104
R. diacantha	8	.90	1,025
R. americanum	12	.50	1,725
R. nigrum	12	1.44	725
R. fasciculatum	6	.72	690
R. alpinum	16	1.20	828
R. sativum	13	1.92	800
R. luridum	13	.96	690
R. stenocarpum	12	.56	1,173
R. vilmorinii	13	.56	828
R. missouriense	13	.72	800
R. cynobasti	16	.98	1,035
R. hirtellum	14	1 44	866

TABLE V.—Showing the average length in millimeters of tracheal elements, tracheids, and wood fibers in the different species.

	Average length of tracheal element.	Average length tracheid.	Average length wood fiber.
	mm.	mm.	mm.
R. holosericeum	0.45	0.43	0.41
R. tenue	.35	.32	.55
R. aureum	.26	.20	:27
R. diacantha	.37	.21	.47
R. americanum	.34	.22	.27
R. nigrum	.36	.25	.40
R. fasciculatum	.28	.36	.37
R. alpinum	.25	.21	.30
R. sativum	.22	.28	.22
R. luridum	.41	.23	.28
R. stenocarpum	.32	.40	.37
R. vilmorinii	.25	.22	.46
R. missouriense	.30	.28	.41
R. cynobasti	.37	.21	.50
R. hirtellum	.22	.46	.32

There is little or no correlation in length of any two of these elements in all of the different species. There is little or no variation in size or shape of the xylem parenchyma cells in the different species. These cells measure approximately .025 mm. in cross diameter and .062 mm. in vertical length. There is considerable variation in the amount and distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the stem as shown in Table I.

SUMMARY OF LEAVES

The leaves of all of the fifteen species of *Ribes* studied have the following features in common: Three to five lobed, palmately veined leaves with dentate margins; three main veins extending from the base of the blade to the tips of the lobes, giving off numerous side branches (Plate XLVII); the upper epidermal cells (Plate XLVI) the larger and with walls thicker than those of the lower epidermis; the outer wall of the epidermal cells of the blade and petiole projecting and overlaid by a thin cuticle; stomata occurring only in the lower epidermis in all species except *R. aureum;* no bast fibers in the leaf blade; the midrib with relatively thin-walled strengthening tissue extending from epidermis to epidermis; from 1 to 3 layers of palisade cells composing from ⅓ to ½ of the mesophyll volume (Plate XLVI); either a single 3-lobed vascular bundle or 3 separate vascular bundles entering the petiole; the lobes or bundles tending to fuse on passing to the blade (Plate XLV, figs. 16-30).

Table VI shows the variation in average length of leaves and average width and thickness of petioles in the different species. The leaf varies in width from less than ½ its length in *R. stenocarpum* and *R. diacantha* to nearly equal its length in *R. missouriense.* There is a fair correlation between the length of leaf, width of leaf, and length of petiole. There is considerable variation in the thickness of the leaf blade, which ranges from .12 mm. in *R. americanum* to .26 mm. in *R. diacantha.* The variation in thickness of petioles ranges from .50 mm. in *R. vilmorinii* to 1.28 mm. in *R. sativum.* (Plate XLV, figs. 16-30). The radial walls of the epidermal cells (Plate XLIII, figs. 29-54) are slightly undulated in all except the following five species: *R. holosericeum, R. aureum, R. diacantha, R. stenocarpum,* and *R. cynobasti.* All have trichomes (Plate XLIII, figs. 7-13) except *R. aureum* and *R. diacantha;* however, there is considerable variation in amount, length, and distribution of trichomes in the different species. Trichomes are sparse in the following species: *R. holosericeum, R. tenue, R. nigrum, R. alpinum,* and *R.*

TABLE VI.—Showing the average length of leaves, width and thickness of blades, and length and thickness of petioles.

	Length of leaf.	Width of leaf.	Thickness of blade.	Length of petiole.	Thickness of petiole.
	mm.	mm.	mm.	mm.	mm.
R. holosericeum	55	40	0.24	17	0.92
R. tenue	25.5	17.5	.26	6	.64
R. aureum	40	24.5	.17	18	.56
R. diacantha	30.5	14	.26	8	.74
R. americanum	50	37.5	.12	18	.64
R. nigrum	67.5	40	.16	23.5	.90
R. fasciculatum	42.5	33	.15	12	.68
R. alpinum	18.5	12	.24	7	.64
R. sativum	54.5	44.5	.14	16.5	1.28
R. luridum	55	29	.24	21	1.12
R. stenocarpum	27.5	10.5	.20	10.5	.69
R. vilmorinii	27.5	19	.16	11.5	.50
R. missouriense	31	30	.18	10	.96
R. cynobasti	37.5	26.5	.17	10	.80
R. hirtellum	32	18.5	.16	16	.64

luridum; moderate in number in *R. americanum* and *R. hirtellum*; and abundant in the remaining species. The average length of trichomes in mm. in the various species is as follows: *R. americanum* .05; *R. alpinum, R. luridum,* and *R. vilmorinii* .10; *R. hirtellum* and *R. nigrum* .14 and .16, respectively; *R. stenocarpum, R. tenue, R. fascicullatum, R. missouriense,* and *R. cynobasti* .23, .24, .26, .28 and .29, respectively; *R. holosericeum* .35 and *R. sativum* .36. Trichomes are found on both the upper and lower epidermis of the blade and on the petiole of the following species: *R. holosericeum, R. americanum, R. nigrum, R. fasciculatum, R. sativum, R. stenocarpum,* and *R. vilmorinii.* *R. alpinum* has a few trichomes mostly at the margin. *R. luridum* has a small amount of trichomes with the epidermis of the petiole, margin and upper epidermis of the blade. *R. missouriense* has a moderate amount with the epidermis of the petiole, margin and upper epidermis of the blade. *R. cynobasti* and *R. hirtellum* have trichomes with both the upper and lower epidermis of the blade. *R. tenue, R. americanum, R. missouriense,* and *R. cynobasti* have multicellular trichomes and *R. sativum* multicellular, branched trichomes along the borders of the groove of the petiole. There are multicellular sessile glands with

the epidermis of *R. americanum* and *R. nigrum,* and multicellular stalked glands, with a several-celled stalk with the epidermis of *R. alpinum* and *R. cynobasti.* Table VII shows the number of stomata and palisade cells per square mm. of leaf area and the average length of palisade cells in the different species. There is a slight correlation between the number of stomata and palisade cells per square mm. of leaf area. The ratio of palisade cells to stomata varies from 14 to 1 in *R. fasciculatum* to 30 to 1 in *R. tenue.* The length of palisade cells varies from .03 mm. in *R. tenue* and *R. aureum* to .06 mm. in *R. alpinum* (Plate XLVI). It is interesting to note that *R. tenue* and *R. aureum,* with the highest ratio of palisade cells to stomata, have the shortest palisade cells. The number of meshes per square mm. of leaf area varies from 12 in *R. tenue* to 35 in *R. hirtellum.* The number of veinlet ends terminating within the mesophyll per square mm. of leaf area varies from 5 in *R. tenue* and *R. alpinum* to 26 in *R. hirtellum* and *R. vilmorinii.* There is some correlation between the number of meshes and veinlet ends in the different species. There is considerable variation in size and shape of the midribs and vascular bundles as seen in cross sections (Plate XLV, figs. 1-15). The midribs vary in thickness from .24

TABLE VII.—Showing the number of stomata and palisade cells per square mm. of leaf area and the average length of palisade cells.

	Number of stomata.	Number of palisade cells.	Average length of palisade cells.
R. holosericeum	342	5,635	0,05
R. tenue	207	6,210	.03
R. aureum	245	6,831	.03
R. diacantha	201	3,726	.05
R. americanum	432	6,240	.04
R. nigrum	276	5,380	.04
R. fasciculatum	242	3,405	.04
R. alpinum	207	5,000	.06
R. sativum	208	3,933	04
R. luridum	276	5,589	.055
R. stenocarpum	250	4,967	.05
R. vilmorinii	414	6,240	.04
R. missouriense	167	3,519	.04
R. cynobasti	208	5,589	.04
R. hirtellum	310	5,616	.04

mm. in *R. aureum*, *R. diacantha*, *R. americanum*, and *R. stenocarpum* to .54 mm. in *R. nigrum*. The upper surface of the midrib varies in shape from nearly flat to decidedly V-shaped, with the lower surface rounded. The midrib with relatively thin-walled strengthening tissue extends from epidermis to epidermis. The leaf margin is rounded in all species except *R. missouriense*, *R. vilmorinii* and *R. cynobasti*, which have pointed margins, as seen in cross section (Plate XLVI). The palisade cells extend to the margin in all species except *R. holosericeum*. In most species, cells the size and shape of the upper epidermal cells extend around to the lower surface where there is an abrupt transition in size and shape to that of the typical lower epidermal cells. There is considerable variation in size and shape of petioles in the different species (Plate XLV, figs. 16-30). The upper surface of the petiole is concave in most species and ranges from nearly flat to distinctly V-shaped with the lower surface rounded. The upper surface is slightly convex in *R. hirtellum*, *R. diacantha*, *R. missouriense*, and *R. aureum*. The petiole is triangular in outline in *R. nigrum* and inverted dome-shaped in *R. sativum*. Bast fibers bordering the outer edge of the phloëm were found in all species except *R. alpinum* and *R. stenocarpum*, the number of cell layers varying from 1 to 6 among the different species (Plate XLV, figs. 16-30). There are 3 separate vascular bundles entering the base of the petiole in all species except *R. americanum*, *R. stenocarpum*, and *R. missouriense*, which have a single 3-lobed bundle. The lobes of the single bundle tend to disappear on passing to the blade, and the three separate bundles fuse into one in all species except *R. diacantha* and *R. sativum*. There is some variation in the rapidity and amount of fusion of vascular bundles in the different species.

KEY TO STEMS

I. Collenchyma typical.
  - A. More than one ring of peridermal tissue in 2 years' growth, stem unarmed. *R. missouriense*.
  - B. One ring of peridermal tissue in 2 years' growth, stem armed.
    1. Radial walls of the epidermal cells cutinized .... *R. stenocarpum*.
    2. Radial walls of the epidermal cells not cutinized .... *R. cynobasti*.

II. Collenchyma not typical.
  - A. Trichomes present.
    1. Radial walls of the epidermal cells cutinized.
      - a. Multicellular, sessile glands present.
        - (1) Average cross diameter of tracheal tubes less than .025 mm... *R. americanum*.
        - (2) Average cross diameter of tracheal tubes more than .025 mm.... *R. nigrum*.
      - b. Glands absent.
        - (1) Average less than 865 tracheal tubes per square mm. of xylem area. *R. fasciculatum*.
        - (2) Average more than 865 tracheal tubes per square mm. of xylem area. *R. holosericeum*.

2. Radial walls of epidermal cells not cutinized.
   a. Average more than 1050 tracheal tubes per square mm. of xylem area. . *R. tenue.*
   b. Average less than 1050 tracheal tubes per square mm. of xylem area.
      (1) Peridermal tissue formed at outer edge of phloëm. . . . . *R. vilmorinii.*
      (2) Peridermal tissue formed in midst of cortex. . . . . *R. sativum.*

B. Trichomes absent.
   1. Radial walls of epidermal cells cutinized.
      a. Outer wall of epidermal cells hardly at all projecting. . . . . *R. alpinum.*
      b. Outer wall of epidermal cells decidedly projecting.
         (1) Largest tracheal tubes less than .022 mm. in cross diameter. . . *R. diacantha.*
         (2) Largest tracheal tubes greater than .022 mm. in cross diameter. . *R. luridum.*
   2. Radial walls of epidermal cells not cutinized.
      a. Less than 13 protoxylem points in stem cross section. . . . . *R. aureum.*
      b. More than 13 protoxylem points in stem cross section. . . . . *R. hirtellum.*

KEY TO PETIOLES

I. Bast fibers absent.
   A. Vascular bundle fan-shaped as seen in cross section. . . . . *R. alpinum.*
   B. Vascular bundle circular as seen in cross section. . . . . *R. stenocarpum.*

II. Bast fibers present.
   A. One vascular bundle at base of petiole.
      1. Sclerenchyma thick walled with small intercellular space. . . . . *R. missouriense.*
      2. Sclerenchyma relatively thin-walled with relatively large intercellular space.
         a. Vascular bundle in the shape of a circle, 3-lobed, and fan-shaped as seen in a cross section midway between leaf base and leaf blade. . . . *R. americanum.*
         b. Vascular bundle bent in the shape of a semicircle and not 3-lobed as seen in a cross section midway between leaf base and leaf blade. . . . *R. fasciculatum.*
   B. Three vascular bundles at base of petiole.
      1. Two or more distinct bundles at apex of petiole.
         a. A bundle system of three equal-sized triangularly arranged bundles, with entire outer edge of phloëm bordered by sclerenchyma. . . . . *R. sativum.*
         b. A bundle system consisting of unequal-sized bundles not triangularly arranged, with only part of outer edge of phloëm bordered by sclerenchyma . . . . *R. diacantha.*
      2. One bundle at the apex of petiole.
         a. Bundle cross section 3-lobed at apex of the petiole.
            (1) Petiole cross section is triangular in outline at a point midway between leaf base and leaf blade. . . . . *R. nigrum.*
            (2) Petiole cross section is inverted dome-shaped at a point midway between leaf base and leaf blade. . . . . *R. holosericeum.*
         b. Bundle cross section not 3-lobed at apex of petiole.
            (1) Bundle cross section at apex of petiole is only slightly bent.
               (a) Three separate bundles bordered by relatively thick-walled sclerenchyma midway between leaf base and leaf blade. . . . . *R. luridum.*
               (b) One bundle bordered by relatively thin-walled sclerenchyma midway between leaf base and leaf blade.
                  1. Bundle cross section midway between leaf base and blade is circular in outline. . . . . *R. aureum.*
                  2. Bundle cross section midway between leaf base and blade is 3-lobed and fan-shaped. . . . . *R. vilmorinii.*
            (2) Bundle cross section at apex of petiole is bent in the shape of a semicircle.
               (a) One fan-shaped bundle seen in a cross section midway between leaf base and blade. . . . . *R. cynobasti.*
               (b) Three separate bundles midway between leaf base and blade.
                  1. Sclerenchyma relatively thin-walled with relatively large intercellular space . . . . *R. hirtellum.*
                  2. Sclerenchyma relatively thick-walled with relatively small intercellular space . . . . *R. tenue.*

KEY TO MIDRIBS

I. Upper surface of midrib U-shaped..*R. nigrum.*
II. Upper surface of midrib narrow to broadly V-shaped.
 A. Palisade cells one layered throughout the leaf....................*R. missouriense.*
 B. Palisade cells ranging from one to two layers throughout the leaf.
  a. Vascular bundle fan-shaped as seen in cross section.
   1. Lower epidermis beset with multicellular, sessile glands.......*R. americanum.*
   2. Glands absent ....*R. sativum.*
  b. Vascular bundle nearly a circle in outline as seen in cross section.
   1. Leaf blade sharply decreasing in thickness on approaching the midrib. *R. holosericeum.*
   2. Leaf blade not decreasing in thickness on approaching the midrib.
    (a) Vertical thickness of midrib more than twice that of the blade. *R. vilmorinii.*
    (b) Vertical thickness of midrib less than one and a half that of the blade ....*R. stenocarpum.*
 C. Palisade cells two layered throughout the leaf.
  a. Two-thirds of the midrib projecting below the leaf blade.........*R. hirtellum.*
  b. About one-third of the midrib projecting below the leaf blade........*R. tenue.*
III. Upper surface of midrib nearly flat.
 A. Midrib decidedly projecting below the leaf blade....................*R. cynobasti.*
 B. Midrib not decidedly projecting below the leaf blade.
  a. Outer walls of the upper epidermal cells decidedly projecting.........*R. aureum.*
  b. Outer walls of the upper epidermal cells only slightly projecting.
   1. Tangential diameter of vascular bundles greater than vertical diameter. *R. luridum.*
   2. Vertical diameter of vascular bundle greater than tangential diameter. *R. diacantha.*
IV. Upper surface of midrib slightly concave.
 A. Outer walls of upper epidermal cells decidedly projecting...........*R. fasciculatum.*
 B. Outer walls of upper epidermal cells only slightly projecting..........*R. alpinum.*

KEY TO MARGINS

I. Blade cross section rounded at the margin.
 A. Blade cross section less than .11 mm. thick at a point .125 mm. from the margin ....*R. americanum.*
 B. Blade cross section between .11 and 16 mm. thick at a point .125 mm. from the margin.
  a. Margin roughened ....*R. hirtellum.*
  b. Margin not roughened.
   1. Outer walls of epidermals cells relatively thick..............*R. fasciculatum.*
   2. Outer walls of epidermal cells relatively thin.
    (a) Palisade cells not extending to the margin..............*R. holosericeum.*
    (b) Palisade cells extending to the margin.
     (1) Lower epidermis beset with multicellular, sessile glands....*R. nigrum.*
     (2) Glands absent.
      *Mostly two layers of palisade cells................*R. stenocarpum.*
      **Mostly one layer of palisade cells....................*R. sativum.*
 C. Blade cross section greater than .16 mm. at a point .125 mm. from the margin.
  a. Average length of cells in the upper palisade layer greater than .035 mm.
   1. Blade cross section less than .21 mm. thick at a point .125 mm. from the margin ....*R. alpinum.*
   2. Blade cross section greater than .21 mm. at a point .125 mm. from the margin.
    (a) Outer walls of epidermal cells relatively thick..............*R. diacantha.*
    (b) Outer walls of epidermal cells relatively thin................*R. luridum.*
  b. Average length of cells in the upper palisade layer less than .035 mm.
   1. Stomata present in the upper epidermis.........................*R. aureum.*
   2. Stomata absent in the upper epidermis............................*R. tenue.*

II. Blade cross section pointed at the margin.
  A. Upper epidermal cells relatively thick.............................. *R. cynobasti.*
  B. Upper epidermal cells relatively thin.
    a. Upper surface of margin curved and lower surface straight...... *R. missouriense*
    b. Margin wedge-shaped.. *R. vilmorinii*

SUMMARY AND CONCLUSION

An examination of the data given in the summary of stem and leaf features leads one to the conclusion that all fifteen species agree in the general plan of their anatomical structure. It is also evident that species which show a close agreement in the details of their anatomical structure also show a close agreement in their larger morphological features.

In comparing a large number of species which are similar in some structural features and dissimilar in others we may divide them into two or more groups on the basis of this situation. By using many such features a large number of different groupings may be obtained. Assuming the inheritance of these different features to be of equal persistence, and knowing the plants have been raised under the same environmental conditions, then the frequency with which any two species fall within the same group may be used as an indication of the closeness of their genealogical relationship. Table VIII, based on eighteen anatomical features not common to all species, shows at a glance the frequency with which each species falls in the same group with each of the other species. The eighteen following features were used in making the table: Amount and distribution of trichomes of the leaf epidermis; absence or kinds of glands of the epidermis present; shape of leaf epidermal cells; shape of leaf tip; shape of leaf margin; shape of midrib; number of layers of palisade cells; number of vascular bundles entering the petiole; presence or absence of trichomes of the stem epidermis; presence or absence of bast fibers in the petiole; stem armed or unarmed; shape and size of stem epidermal cells; cutinization of radial walls of stem epidermal cells; kinds of collenchyma; number of rings of peridermal tissue in the two years' growth; number of protoxylem points; length of xylem elements; and the distribution of starch, tannin and cluster crystals of calcium oxalate in the tissues of the stem and leaf. There are many features that are common to all species given in the summary of stems and leaves. The table indicates that there are many instances of similarities of anatomical features between American and European species. The three highest frequencies obtained are between some American and European species, and the lowest between some American species and between American and European species.

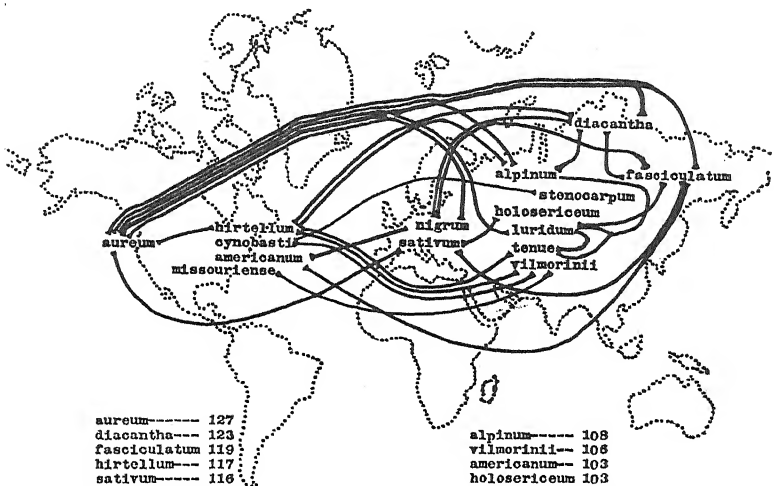
TABLE VIII.—Showing the frequency with which any two species fall into the same group on the basis of their similarity of features

103	holosericeum..	1															
110	tenue	2	8														
127	*aureum.......	3	8	8													
123	diacantha.....	4	8	8	16												
103	*americanum...	5	8	6	9	8											
108	nigrum.......	6	8	7	11	10	14										
119	fasciculatum..	7	9	8	12	10	10	10									
118	alpinum......	8	6	10	11	10	8	8	7								
116	sativum......	9	10	8	10	9	7	9	11	7							
114	luridum......	10	7	11	10	10	7	8	10	10	9						
74	stenocarpum..	11	4	7	7	6	5	4	4	6	4	6					
106	vilmorinii	12	8	9	7	7	5	5	8	6	9	9	4				
66	*missouriense ..	13	5	4	3	3	5	3	6	3	8	3	3	9			
18	*cynobasti.....	14	5	6	5	7	3	4	5	6	6	5	8	10	5		
117	*hirtellum.....	15	9	10	10	11	8	7	9	10	9	9	6	10	6	3	
			1	2	3 *	4	5 *	6	7	8	9	10	11	12	13 *	14 *	15 *

* Indicates American species.
Nos. 1-15 outside the square are used as symbols for the different species.
The numbers inside the square represent frequencies.
The numbers preceding the names are total frequencies.

Figure I is a map of the world showing the relative position of the various continental masses as they appear to-day. The name of each of the fifteen species appears on the particular continent or part of a continent to which the species is native. Lines are drawn connecting species between which a relatively high degree of anatomical relationship was found in Table VIII. The table in figure I shows the degree of anatomical relationship of each of the fifteen species with all other species and is obtained from Table VIII by combining the frequencies with which each species falls within the same group with each of the other species.

Figure I shows at a glance that there are numerous instances of a relatively close anatomical relationship between species isolated on different continents. It also shows that there are several species (*R. cynobasti, R. stenocarpum,* and *R. missouriense*) which show but little anatomical relationship to other species, even to those found on the same continent. For example, the two highest degrees of anatomical relationship found were between *R. aureum* (West N. A.) and *R. diacantha* (North Asia) and between *R. americanum* (East N. A.) and *R. nigrum* (North Eu). The question arises, how could species isolated on such remote parts of the earth come to



aureum------	127	alpinum-----	108
diacantha---	123	vilmorinii--	106
fasciculatum	119	americanum--	103
hirtellum---	117	holosericeum	103
sativum-----	116	cynobasti---	78
luridum-----	114	stenocarpum-	74
tenue-------	110	missouriense	66
nigrum------	108		

FIGURE I

have such a close degree of anatomical correspondence? It cannot be explained by hybridization, and it is very improbable that they may have mutated in the same direction. A more suitable explanation is furnished by assuming a former connection of these continents, either by land bridges or by their being formerly collected together into a single continental mass which later separated and its fragments drifted apart. Such a theory is furnished by Koppen and Wegener (1924), and is favorably regarded by Zimmermann (1930) and Seward (1931). According to this theory the Eastern coast of North America was in former contact with Europe and the Western coast of North America was in former contact with Asia, which accounts for the close anatomical correspondence between *R. americanum* and *R. nigrum* and between *R. aureum* and *R. diacantha*. The numerous lines on the map connecting *R. aureum* with many other species on both continents and the high degree (127) of anatomical relationship to all other species shown in the accompanying table below the map, indicates that *R. aureum* either belongs to or is closely related to the original hypothetical stock of *Ribes* from which all other species descended. It is also observed that the fifteen species are listed in the table in a descending order from the original stock (*i. e.*, the smaller the number the less anatomical correspondence with other species and the further the descent from the original stock). The small degree of anatomical correspondence of *R. cynobasti*, *R. stenocarpum*, and *R. missouriense* with other species would seem to indicate that they have probably originated by mutation.

PLATE XLIII

TRICHOMES (× 135)

FIG. 1. Stem trichome of *R. americanum*.
FIG. 2. Stem trichome of *R. vilmorinii*.
FIG. 3. Stem trichome of *R. stenocarpum*.
FIG. 4. Stem trichome of *R. holosericeum*.
FIG. 5. Stem trichome of *R. sativum*.
FIG. 6. Stem trichome of *R. fasciculatum*.
FIG. 7. Leaf trichome of *R. missouriense*.
FIG. 8. Leaf trichome of *R. nigrum*.
FIG. 9. Leaf trichome of *R. fasciculatum*.
FIG. 10. Leaf trichome of *R. cynobasti*.
FIG. 11. Leaf trichome of *R. stenocarpum*.
FIG. 12. Leaf trichome of *R. vilmorinii*.
FIG. 13. Leaf trichome of *R. hirtellum*.

EPIDERMISES (× 135)

FIG. 14. Stem epidermis of *R. tenue*.
FIG. 15. Stem epidermis of *R. fasciculatum*.
FIG. 16. Stem epidermis of *R. aureum*.
FIG. 17. Stem epidermis of *R. hirtellum*.
FIG. 18. Stem epidermis of *R. sativum*.
FIG. 19. Stem epidermis of *R. missouriense*.
FIG. 20. Stem epidermis of *R. vilmorinii*.
FIG. 21. Stem epidermis of *R. alpinum*.
FIG. 22. Stem epidermis of *R. stenocarpum*.
FIG. 23. Stem epidermis of *R. holosericeum*.
FIG. 24. Stem epidermis of *R. nigrum*.
FIG. 25. Stem epidermis of *R. luridum*.
FIG. 26. Stem epidermis of *R. cynobasti*.
FIG. 27. Stem epidermis of *R. diacantha* (female).
FIG. 28. Stem epidermis of *R. americanum*.
FIG. 29. Lower leaf epidermis of *R. luridum*.
FIG. 30. Upper leaf epidermis of *R. hirtellum*.
FIG. 31. Lower leaf epidermis of *R. stenocarpum*.
FIG. 32. Upper leaf epidermis of *R. stenocarpum*.
FIG. 33. Lower leaf epidermis of *R. americanum*.
FIG. 34. Upper leaf epidermis of *R. americanum*.
FIG. 35. Lower leaf epidermis of *R. holosericeum*.
FIG. 36. Upper leaf epidermis of *R. luridum*.
FIG. 37. Lower leaf epidermis of *R. hirtellum*.
FIG. 38. Upper leaf epidermis of *R. cynobasti*.
FIG. 39. Lower leaf epidermis of *R. cynobasti*.
FIG. 40. Lower leaf epidermis of *R. alpinum*.
FIG. 41. Upper leaf epidermis of *R. alpinum*.
FIG. 42. Lower leaf epidermis of *R. fasciculatum*.
FIG. 43. Upper leaf epidermis of *R. holosericeum*.
FIG. 44. Upper leaf epidermis of *R. vilmorinii*.
FIG. 45. Lower leaf epidermis of *R. vilmorinii*.
FIG. 46. Lower leaf epidermis of *R. sativum*.
FIG. 47. Upper leaf epidermis of *R. nigrum*.
FIG. 48. Lower leaf epidermis of *R. nigrum*.
FIG. 49. Upper leaf epidermis of *R. fasciculatum*.
FIG. 50. Upper leaf epidermis of *R. diacantha*.
FIG. 51. Upper leaf epidermis of *R. sativum*.
FIG. 52. Upper leaf epidermis of *R. missouriense*.
FIG. 53. Lower leaf epidermis of *R. missouriense*.
FIG. 54. Lower leaf epidermis of *R. diacantha*.

PLATE XLIII

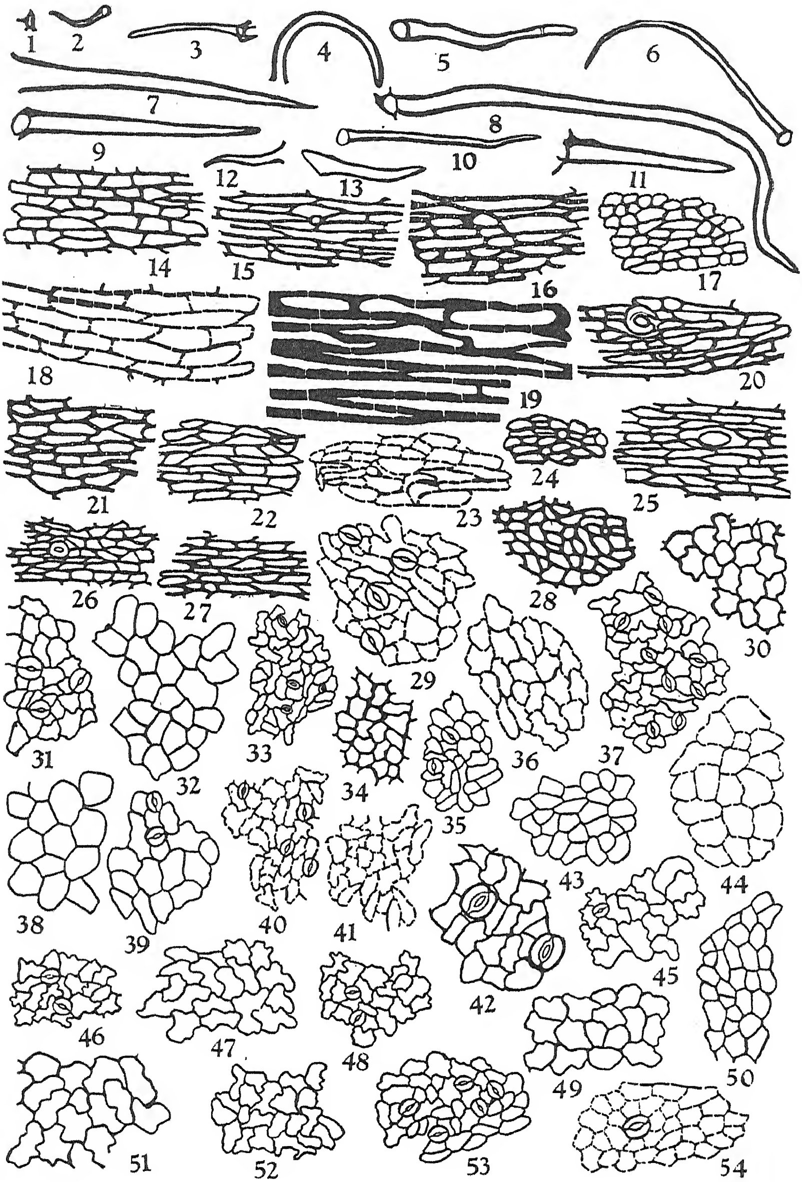

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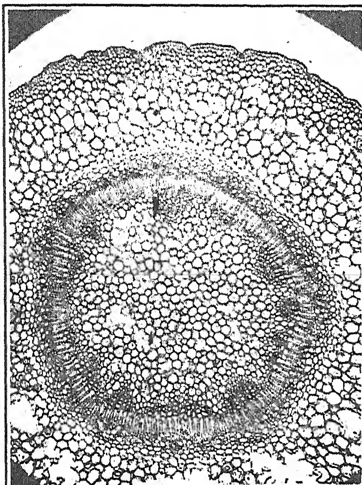
PLATE XLIV

TYPICAL STEM CROSS SECTIONS (× 48)

FIG. 1. Stem section of *R. vilmorinii* in the primary condition.
FIG. 2. Stem section of *R. missouriense* taken from current year's growth.
FIG. 3. Stem section of *R. nigrum* taken from current year's growth.
FIG. 4. Stem section of *R. hirtellum* taken from two years' growth.

PLATE XLIV



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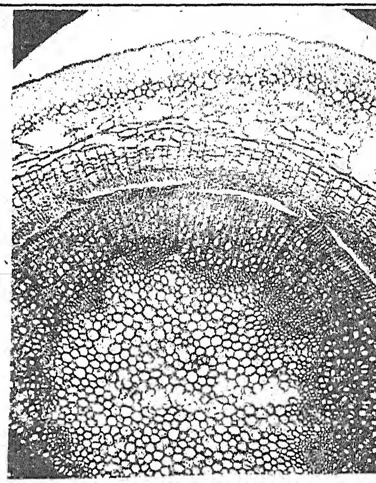

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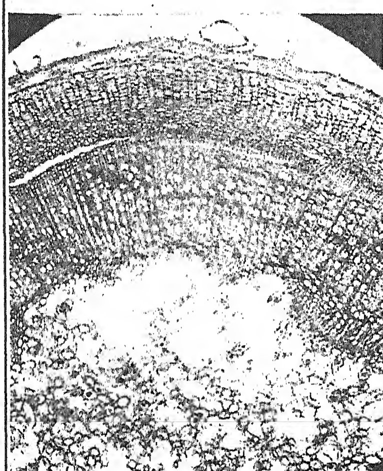

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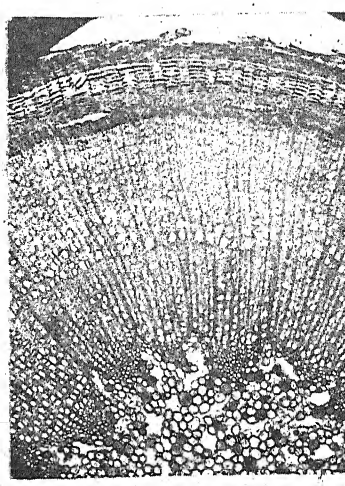

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PLATE XLV

MIDRIB CROSS SECTIONS (×48)

FIG. 1. *R. missouriense.*
FIG. 2. *R. tenue.*
FIG. 3. *R. fasciculatum.*
FIG. 4. *R. aureum.*
FIG. 5. *R. vilmorinii.*
FIG. 6. *R. nigrum.*
FIG. 7. *R. luridum.*
FIG. 8. *R. cynobasti.*
FIG. 9. *R. americanum.*
FIG. 10. *R. stenocarpum.*
FIG. 11. *R. diacantha.*
FIG. 12. *R. hirtellum.*
FIG. 13. *R. alpinum.*
FIG. 14. *R. sativum.*
FIG. 15. *R. holosericeum.*

PETIOLE CROSS SECTIONS (×48)

FIG. 16. *R. cynobasti.*
FIG. 17. *R. vilmorinii.*
FIG. 18. *R. holosericeum.*
FIG. 19. *R. luridum.*
FIG. 20. *R. alpinum.*
FIG. 21. *R. nigrum.*
FIG. 22. *R. hirtellum.*
FIG. 23. *R. diacantha.*
FIG. 24. *R. aureum.*
FIG. 25. *R. tenue.*
FIG. 26. *R. americanum.*
FIG. 27. *R. stenocarpum.*
FIG. 28. *R. fasciculatum.*
FIG. 29. *R. sativum.*
FIG. 30. *R. missouriense.*

PLATE XLV


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PLATE XLVI

EPIDERMISES (× 135)

FIG. 1. Lower leaf epidermis of *R. aureum*.
FIG. 2. Upper leaf epidermis of *R. aureum*.
FIG. 3. Lower leaf epidermis of *R. tenue*.
FIG. 4. Upper leaf epidermis of *R. tenue*.

MARGINS OF THE LEAVES (× 165)

FIG. 5. Leaf margin of *R. americanum*.
FIG. 6. Leaf margin of *R. nigrum*.
FIG. 7. Leaf margin of *R. vilmorinii*.
FIG. 8. Leaf margin of *R. hirtellum*.
FIG. 9. Leaf margin of *R. stenocarpum*.
FIG. 10. Leaf margin of *R. fasciculatum*.
FIG. 11. Leaf margin of *R. missouriense*.
FIG. 12. Leaf margin of *R. alpinum*.
FIG. 13. Leaf margin of *R. holosericeum*.
FIG. 14. Leaf margin of *R. cynobasti*.
FIG. 15. Leaf margin of *R. diacantha*.
FIG. 16. Leaf margin of *R. sativum*.
FIG. 17. Leaf margin of *R. aureum*.
FIG. 18. Leaf margin of *R. luridum*.
FIG. 19. Leaf margin of *R. tenue*.

PLATE XLVI

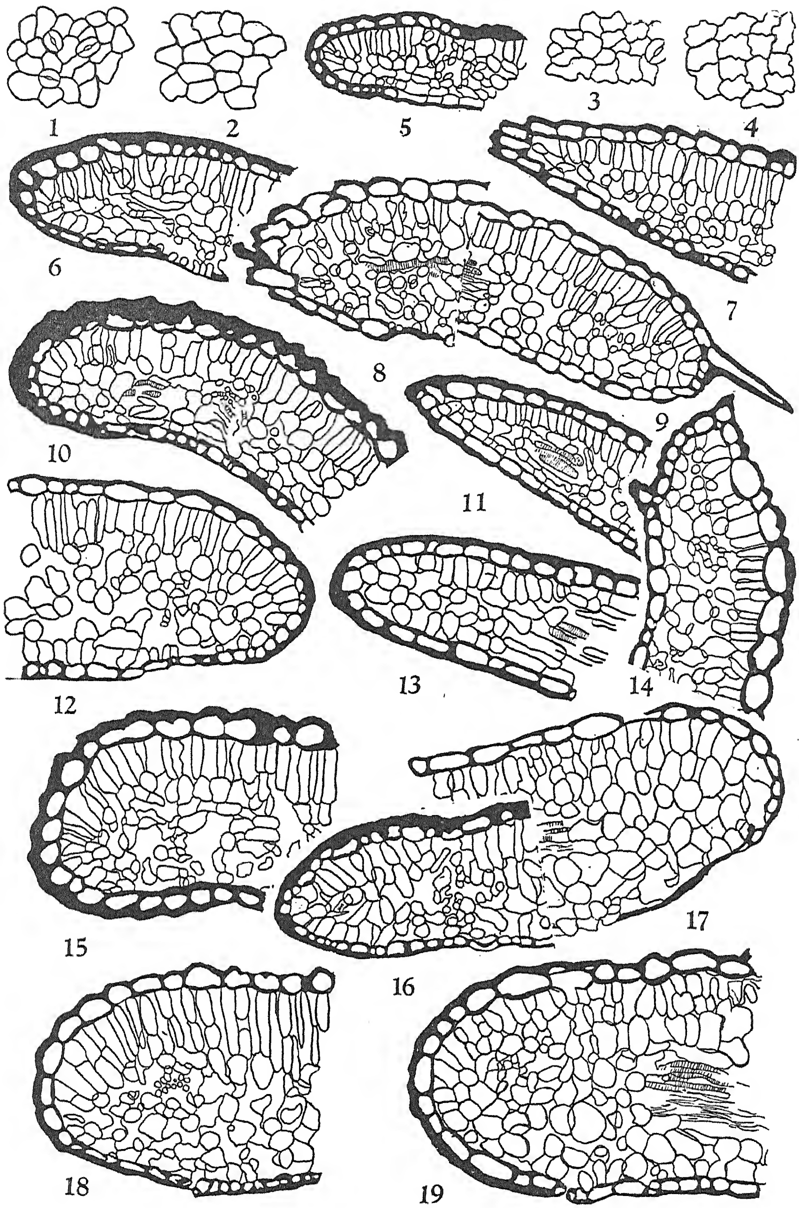
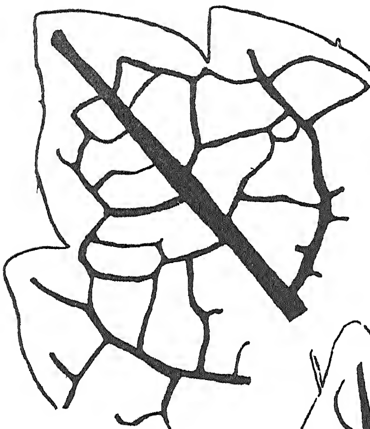


PLATE XLVII

TYPICAL LEAF VENATION (× 28)

FIG. 1. Leaf venation of *R. alpinum*.
FIG. 2. Leaf venation of *R. stenocarpum*.
FIG. 3. Leaf venation of *R. americanum*.
FIG. 4. Leaf venation of *R. hirtellum*.
FIG. 5. Leaf venation of *R. sativum*.

PLATE XLVII



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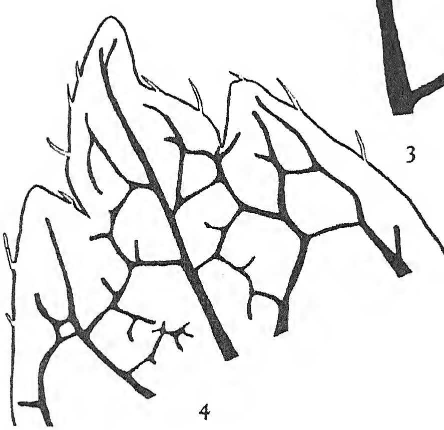

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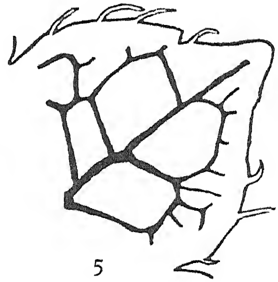

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Morphology and Anatomy of *Mollugo verticillata* L.

SISTER M. ANTHONY PAYNE, O. S. B.

ABSTRACT: The probable relationship of the Aizoaceæ to the Phytolaccaceæ is analyzed, as well as its relationship to the Chenopodiaceæ, Portulacaceæ and Caryophyllaceæ. *Mollugo verticillata,* the "carpet weed," belongs to the family Aizoaceæ, which is principally tropical, containing 18 genera and 600 species.

Mollugo, found in temperate climes, has twelve to eighteen radiating stems which crown a tapering root and lie prostrate on the ground. The leaves are in small whorls, and the inconspicuous flowers are borne on slender pedicels. They are perfect, but incomplete. Three stamens alternate with the locules of the three-chambered ovary, which contains about thirty kidney-shaped seeds.

The thickened spatulate leaf has stomata on both surfaces and vestigial trichome bases on the upper epidermis. The mesophyll is about eight layers in thickness. Numerous translucent, simple crystals abound in the mesophyll of the leaf and in the cortical tissue of the stem. The crystals are probably calcium oxalate, for they refract interference colors of the third order. The structure of older portions of stems varies between nodes and intenodes, while pseudoannulation occurs in cross sections of both stem and root. The units which form the tracheal tubes are heavily pitted. The dense cylindrical arrangement of tracheal tubes and lignified tracheids, followed by a cylinder of less compactly disposed tubes and fibrous tracheids, given the impression of annual rings.

Drawings and photomicrographs illustrate various points in the paper.

CLASSIFICATION AND DISTRIBUTION

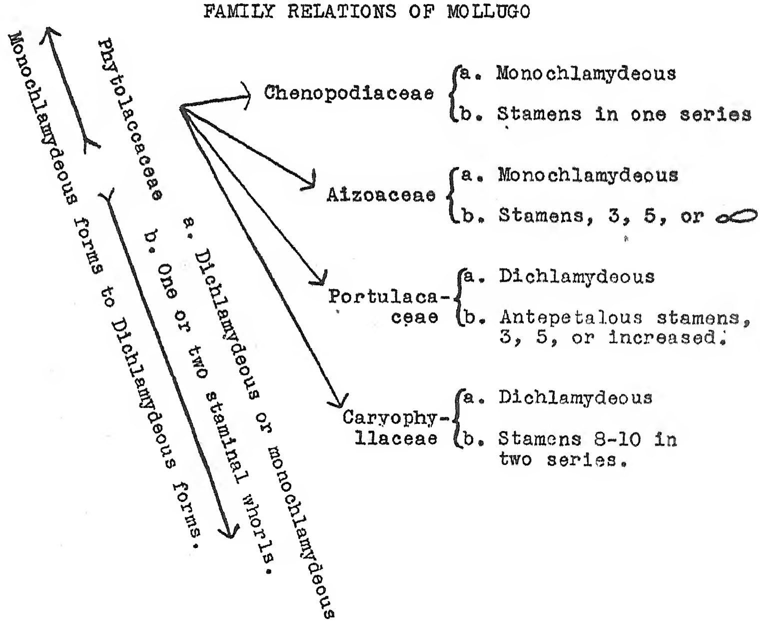
BEFORE discussing the morphology and anatomy of an unfamiliar plant it seems well to classify it, for, although "carpet weeds" may cover the pathway, it is probable that few of them attract curious, much less quizzical, glances. In Rendle's "Classification of Flowering Plants" (1925) *Mollugo verticillata L.* is pigeonholed as follows: Genus and species, *Mollugo verticillata,* of the family Aizoaceæ, order Centrospermæ, and grade Monochlamydeæ.

In the few lines devoted to it by various authors *Mollugo* has been described by comparison with related forms rather than by specific description. Well-known related families are the Chenopodiaceæ, the Phytolaccaceæ, the Portulacaceæ and the Caryophyllaceæ. These families possess in common a characteristically curved embryo surrounding a floury or mealy endosperm, and a central plasenta, to which the seeds are attached.

The small family of the Phytolaccaceæ shows great variety in the plan of structure of the flower, including many apetalous as well as polypetalous forms. Multiple stamens and carpels also occur, and Pax (1892) suggests Phytolaccaceæ as the genetic family of the order Centrospermæ, because in this family are found genera of the monochlamydeous type as well as dichlamydeous forms in which a multiplication of stamens and carpels has occurred. Family relations of *Mollugo* may be illustrated by the following diagram, which readily shows why Gray (1887) first placed *Mollugo* in a suborder of the Caryophyllaceæ and later in the order of the Chenopodiales (1908).

The Aizoaceæ resemble Phytolaccaceæ in their apetalous flowers and in the anomaly of the stem structure of many of its members. It is a miscellaneous group of herbs, shrubs, undershrubs and succu-

FAMILY RELATIONS OF MOLLUGO



lent plants. The family is principally tropical and is found in great numbers in dry places and the warmer parts of the earth, particularly in South America. There are eighteen genera and 600 species. Four hundred of these belong to the genus *Mesembryanthemum*. The familiar ice plant, *M. crystallinum*, is an example of the genus, and thrives in California, Australia and about the Cape. *Mollugo* also is tropical, but it has invaded the northern parts. In 1892 it was reported from central Texas by Mrs. Charles Ward, who collected the specimen for a private herbarium. W. A. Wheeler, in the summer of 1899, collected specimens of *M. verticillata* in the extreme southeastern part of Minnesota, and the specimens on which the present studies were made were collected by W. C. Stevens, professor of botany of Kansas University, near Lawrence, Kansas. Gray's manual (1887) states that although it is an immigrant from farther south, it may be found on sandy river banks, roadsides and in cultivated ground from June to September. The inference is that it is rather common. Its relative unimportance and insignificance accounts, perhaps, for the lack of notation in the literature.

HABITAT AND GENERAL MORPHOLOGY

M. verticillata, the "carpet weed," has many (12-18) slender, jointed branches radiating from the top of a tapering root. The stems are prostrate on the earth and form a rather dense mat that measures 20 to 24 cm. in diameter. The flat patches of greyish green are not showy, for the small spatulate whorls of leaves and the delicate recurved pedicels bearing single flowers are inconspicuous. The flowers form an umbellike cluster. At times they are in the axils of the leaves, but more often five or six flowers are aggregated on one side of the stem while the four or five leaves are crowded in a semiwhorl on the opposite side. Leaves and flowers together suggest the umbel.

The stems are tumid at the nodes, the swellings decreasing in size at nodes farther and farther removed from the root. The main stems are 3.5 mm. in diameter at the point of origin and only 1.5 to 2 mm. in cross section between the third and fourth nodes. They continue to decrease in diameter to the growing tip. The length of the average internode is 25-35 mm.

The main taproot measures 4 mm. in diameter at the point of junction with the stem.

The "carpet weed" can grow in dry, sandy places because of its efficient root system and the water-storing tissue in the leaves and

nodes. The flat mat conserves the moisture in the soil adjacent to the root and the long taproot reaches to depths of 18 to 20 cm. below the surface, while short lateral roots coming from it drain a large area (Pl. XLVIII, fig. 6).

The small hypogynous flowers are borne on slender pedicels at the nodes, the pedicels being as long or slightly longer than the mature capsule, which may measure 4 mm. by 2 mm. The flowers are regular and perfect, but incomplete, having a whitish perianth composed of five small curved sepals, three short stamens with plump anthers alternating with the cells of the ovary, and a short three-parted style over a large three-chambered ovary (Pl. L, figs. 9, 10).

The ovary, when mature, is crowded with large anatropous ovules arranged on axial placentæ. Each locule contains two rows of seeds, one on either side of a partition which extends from the wall of the ovary in the center of each locule nearly to the placentæ. There are generally five or six seeds in a row, each fully developed ovary containing, therefore, about thirty seeds. The seeds are kidney-shaped and a reddish brown. The brittle testa is etched in delicate striæ (Pl. XLVIII, fig. 1) and within, the large embryo is curved peripherally about the fine, starchy endosperm. The epicotyl occupies the upper plump portion of the kidney-shaped seed (Pl. XLVIII, fig. 2).

The simple, entire spatulate to cuneiform leaves occur in whorls or semiwhorls at every node of the stem. There are four to eight leaves in a whorl, unequal in size, even in a single whorl, although the variation in size in the whorl is less than the variation in leaf size between whorls. The leaves that compose the whorls near the point of origin of the stem measure from 15 to 20 mm. by 3 mm. (at the broadest part of the blade), while the leaves composing the distal whorls measure 5 to 10 mm. They are generally pointed, and a few tend to have a mucronate apex (Pl. XLVIII, fig. 10).

ANATOMY

Several methods of procedure were followed in preparing the tissues for microscopic examination. Portions of the specimens had been preserved some months before in equal parts of 95 per cent alcohol and glycerin and were in very good condition. Before embedding in paraffin small pieces of stem, root, leaf, flower and pedicel were dehydrated by the butyl-alcohol method (Zirkle, 1930), and then cut in cross and longitudinal sections varying from 10 to

20 μ in thickness. Some sections were stained in Kernschwartz and safranin, others in gentian-violet and acid-fuchsin. The Kernschwartz and safranin gave good contrast and made delicate cell walls stand out as well as cytoplasmic inclusions. Other sections were simply cleared in chloral hydrate. Others still were treated with various acids in an effort to determine the nature of the crystal inclusions. The endosperm material was tested with Sudan III and a tincture of iodine. Sudan III was also used on freshly mounted cross sections of root and stem. The amount of lignification, as determined by the safranin stain, was checked by the phloroglucin test (Stevens, 1924). The lignified tissue which had been immersed in alcohol containing a trace of phloroglucin turned a deep red when a drop of hydrochloric acid was added.

Sections for photomicrographs were dehydrated and cleared in xylol, then mounted in hyrax. Exposures varying from fourteen seconds to six minutes with an arc light illuminant were made on hard-surface sensitized paper, giving a negative print. A few dry-plate negatives were developed for comparative data.

LEAF

Leaves cleared in chloral hydrate were used for the study of the epidermal layers. In surface view most of the upper epidermal cells are relatively large and irregular with pronounced undulating margins. The length, averaging .082 mm., is more than twice the width (Pl. XLVIII, fig. 11). Over the midrib and larger veins the epidermal cells are elongated and rectangular with regular margins (Pl. XLVIII, fig. 12). A few patches of small, rounded cells can be found on the upper surface of the leaf, while cells much less irregular in contour than the typical undulating epidermal cells stretch out from these areas forming occasional rosettes in the epidermal pattern (Pl. XLVIII, fig. 14). These rosettes suggest the loci of trichomes, but trichomes are lacking in *M. verticillata*. Since, however, so many related forms are hairy it seems probable that this peculiarity is a vestigal remnant of ancestral forms.

The lower epidermis is likewise composed of sinuous cells, but the undulation of the walls is slightly less marked. In some areas the cells approach a rough rectangle in shape.

Stomata occur on both upper and lower surfaces. A stoma is elongate-eliptical in shape and measures about 0.018 mm. in length. Stomata are more numerous on the lower than on the upper surface and are unevenly distributed. The average is 97.1 stomata per sq.

mm. for the upper surface and 117.9 stomata per sq. mm. on the lower surface (Pl. XLVIII, figs. 11 and 16).

Stomata occur frequently in the epidermis of the stem (Pl. XLIX, fig. 7).

A cross section of the leaf (Pl. L, fig. 12) shows a much thickened blade with the region over the midrib depressed. There is a corresponding protrusion of tissue on the ventral surface. Cells of the simple upper epidermis are larger in cross section than cells of the lower epidermis, the former being about two times longer than high and nearly oval (Pl. XLVIII, figs. 13, 15). The outer wall is convex and cutinized, while the inner wall is slightly curved and very thin. Upper epidermal cells average .031 mm. in radial thickness.

Cells forming the lower epidermis have about 0.6 the diameter of the upper epidermal cells. The outer wall is less convex and not as heavily cutinized as in the upper epidermis.

The irregular palisade-parenchyma occurs below the epidermis in two cell layers. The cells are not greatly elongated, some of them being nearly square. In the lower layer many of the palisade forms pass over into a round form. Large intercellular spaces intervene, particularly in the upper row. Some of the palisade cells are typical —narrow and twice as long as neighboring cells. They extend the entire breadth of the palisade parenchyma. These long cells are abundant at the edge of the leaf, and when measured in the surface view average .038 x .033 mm. Conspicuous air spaces are among the palisade cells.

The spongy mesophyll occupies about 0.6 of the thickness of the entire leaf. It is seven or eight layers thick, while the palisade parenchyma occupies only about .25 of the thickness. The border-parenchyma cells are relatively large, sinuous, thin-walled cells, and all the mesophyll in the plane of the veins is unusually large. The midrib is connected to both surfaces of the leaf by collenchyma tissue. The vascular tissue, forming the midrib, is slightly concave above and convex beneath, the phloëm flanking the xylem, largely. There is a tendency for it to completely surround the xylem elements.

The smaller veins are completely immersed in the mesophyll and also have a sinuous parenchyma sheath. A cross section of a leaf shows three or four large lateral bundles to either side of the midrib (Pl. L, fig. 12).

When a cleared leaf is brought in focus the most striking characteristic is the presence of innumerable translucent, simple crystals and tan-colored compound ones. Masses of these splotch the field

in many areas and obscure the underlying tissue (Pl. L, fig. 11). Large ones are scattered at random just under the epidermis, but a rapid shift of focus brings many more from lower levels into view and the impression is gained that the leaf is loaded with crystals. Ten surface counts ranged from 700 to 750 crystals per sq. mm. Fields can be selected, however, in which the count is much higher or much lower. A change of focus to lower depths of the tissue makes an accurate estimate of frequency impossible due to the fact that crystals crowd and overlap from one local plane to another (Pl. L, fig. 8).

The crystals are of two forms although great variation occurs within the classes. One form is the typical spherical rosette and the other is the small, colorless octahedral crystal. Both groups are doubtlessly forms of calcium oxalate ($Ca\ C_2\ O_4\ H_2O$), for they dissolve without effervescence when immersed in a 2 per cent solution of hydrochloric acid. They go into solution slowly, however, for after immersion for thirty or forty minutes all of the crystals may not have disappeared from a cross section of a leaf .012 mm. thick. The very small, simple crystals and the rosette forms disappear first; later the large octahedron type (Rieder, 1899).

The habit of the crystals varies greatly, and an almost endless number of combinations of simple types from acute to obtuse quadratoctahedra occur. Envelope forms, square prisms with pyramidal ends, truncated pyramids, elongated octahedra with bevelled edges or truncated angles are present. Some are imperfectly developed, but most of them can easily be classified as octahedral or twinned octahedral forms.

Multiple twinning of small crystals gives rise to large rosette forms or concretions. Contact twins and penetration twins occur frequently. Twinned structures can be detected by means of the barbed striæ which meet in a line on the face of crystals that at first seem simple. Discs form when oxalate of lime is rapidly precipitated. De Bary states that the form of the crystal depends on the rapidity with which it is deposited. The amount of water of crystallization also varies in the different forms (De Bary, 1884).

With ordinary illumination many of the very small crystals seem irregular or indefinite in outline, but monochromatic light reveals sharp edges and a specific contour. When studied under a polarizing microscope the crystals of *Mollugo* may refract one of several interference colors of the third order; blue, green, greenish-yellow or reddish-violet (Ford, 1922). This difference in the birefringence

is due to the size or thickness of the crystal and its orientation, for the greater the amount of double refraction the higher the order of interference color. The refraction of the colors of the third order supports the evidence from other sources that the crystals are calcium oxalate. (Birefringence of calcium oxalate is .163, the index of refraction for one ray being 1.493, and for the other 1.656.)

Longitudinal and cross sections of the leaves .020 to .040 mm. thick show that crystals of both groups occur plentifully throughout the spongy tissue and in the palisade cells. Rows of simple crystals fill the cells that border the veins (Pl. XLVIII, fig. 9). Small pyramidal forms occur in cells of *Mollugo* more distant from the veins, and a few of the upper epidermal cells have tiny crystals in the vacuoles, but they are the exception, not the rule, while in *Mesembryanthemum lacerum* there are crystals in the epidermal cells in large numbers (De Bary, 1884). The rosette crystals are massed over veins or in areas quite far removed from the main veins. If one rosette crystal occurs in a cell often the six or eight cells adjacent to it are also crystal sacs. The crystals are always suspended in the vacuoles (Pl. XLVIII, fig. 7).

ANATOMY OF STEM

Cross sections and longitudinal sections of stem taken from parts adjacent to the root, at nodes and at internodes were examined. The vascular tissue is cylindrical and surrounds a relatively large homogeneous pith. The simple epidermis is subtended by a cortex which varies in thickness in different regions. Some of the inner cortical cell rows are heavily lignified and sometimes form an undulating fibrous sheath about the vascular tissue, sometimes a broken ring of bast fibers (Pl. XLIX, figs. 5, 6, 7).

The pith consists of several longitudinal rows of large, thin-walled cells, which fill the center of the pith cylinder and are surrounded peripherally by rows of smaller thin-walled cells. The parenchyma cells are very small at the periphery of the pith, measuring in cross section .033 by .041 mm. in diameter. The empty central pith cells are .146 mm. by .061 mm. These, by far the largest cells found in *Mollugo*, in a longitudinal section appear barrel-shaped. The thin walls of the pith cells are finely pitted and small triangular interstices occur among them (Pl. XLIX, fig. 6). Crystals do not occur in pith cells.

There are several rows of protoxylem. Next to the pith a narrow vessel .011 mm. in diameter, with a heavy, loose-coiled spiral occurs,

while further out there is a wider spiral vessel (.015 mm.) with a finer spiral more closely coiled (Pl. LI, fig. 14). Both vessels spiral from left to right. In several longitudinal sections the inner spiral was already distorted through excessive elongation of the branch. A row of thin-walled parenchymatous cells separate the spiral vessels.

The narrow band of protoxylem is followed sometimes by pitted tracheal tubes, sometimes by fiber tracheids. The tracheal tubes always have heavily lignified walls and are scattered irregularly among the thinner-walled xylem parenchyma cells. There are no medullary rays. The large pitted tracheal ducts measure .105 mm. in diameter. These pitted vessels are without any protoplasmic contents, but occasionally crystals and crystal sand occurs. Three large, well-formed rhombohedral crystals in this position are shown in Plate LI, figure 15. The large bordered-pitted vessels are surrounded by fibrous tracheids which vary greatly in size and form. Some tracheids measure only .010 mm. in diameter and are many times longer than wide and have square ends. Others are .32 mm. in diameter and have the end walls at an angle of 40°. The wider tracheids are short and have relatively few pits in the lignified walls. Xylem parenchyma is not abundant. The elements are small, oblong and thin-walled.

In cross sections of larger stems, the dense cylindrical arrangement of tracheal tubes and lignified tracheids, followed by a cylinder of less compactly disposed tubes and fibrous tracheids, gives the impression of annual rings (Pl. XLIX, fig. 7). This pseudoannulation is characteristic likewise of the root.

The phloëm tissue is outside the xylem cylinder only (Pl. XLIX, fig. 4). A cambial layer cannot be distinguished in mature stems. The arrangement of the phloëm differs in cross sections taken at the nodes and between the nodes. The phloëm between the tumid regions about the nodes forms a complete cylinder consisting of three or four rows of sieve tubes, companion cells and phloëm parenchyma surrounded by one or two rows of heavier-walled parenchyma cells. The sieve tubes measure only .002 to .003 mm. in diameter and are associated with companion cells that are even smaller. The tube elements are about .121 mm. in length (Pl. LI, fig. 13).

At nodes the phloëm tissue occurs in small bundles which are separated by rays of parenchyma cells, like extensions from the inner cortex.

The cortex is variable (Pl. XLIX, figs. 1, 2, 4). In cross sections taken from internodes there are six or seven layers of rounded cells. The subepidermal layer is not collenchymatous and no endodermis, as noted above, occurs, but an undulating bast-fiber sheath is one or two rows removed from the phloëm cylinder. The walls of the bast fibers are heavily lignified, in some instances being as thick as the diameter of the lumen of the cell. The fibers may be five or six deep and then gradually decrease until there is only one. A change in the sheath then occurs, for the next cell or two is nonlignified and nonfibrous (Pl. L, fig. 6).

Typical cortical cells are large, rounded and active. The protoplast contains a large nucleus and abundant chloroplasts (Pl. LI, fig. 13). Many of the cortical cells are crystal sacs, large rosette crystals forming in the sap cavities (Pl. XLIX, fig. 2.). These cells have thin walls and measure .039 mm. in diameter. In longitudinal sections hypodermal cells are only slightly elongated, while the deeper cortical cells are nearly twice as long. The bast fibers are twenty times longer than wide. A few small pits occur in the walls (Pl. XLVIII, fig. 8).

In cross section, epidermal cells bulge slightly and are also cutinized (Pl. XLIX, fig. 6). In surface view they are roughly rectangular in outline and measure approximately .113 by .040 mm. Stomata are numerous (Pl. LI, fig. 16).

ROOT

The root of *M. verticillata* is somewhat anomalous in structure in this sense, that elements of the single cylinder of xylem tissue are so distributed that they give the impression of normal annulation. There are three pseudoannular rings of xylem in cross sections of larger roots (Pl. LI, figs. 18, 19), although *M. verticillata* is an annual.

Adjacent to the phloëm there are three rows of tracheal tubes, some of which measure .042 x .146 mm. in diameter, and are therefore the largest elements found in the root. The walls of these tubes are thin and have partially or completely lignified walls. In longitudinal sections, the rims of the dissolved cross walls are remarkably distinct. Groups of nonlignified fiber-tracheids, which measure only .007 to .012 mm. in diameter, are clumped about or between the tracheal tubes.

A cylinder, one to two layers deep, of irregular, small, heavy-walled, lignified tracheids follows the above-described tissue. These

cells are elongated spindles, and it is their arrangement periodically, in rings, that brings about the pseudoannulation. The large, relatively thin-walled tracheal tubes, embedded in clumps of nonlignified fiber-tracheids follow. In a cross section of root 1.056 mm. in diameter, the inner or central "annual ring" measures .273 mm. across and its central mass as well as the three or four peripheral rows of cells are the small, deeply-lignified tracheids, interspersed with the nonlignified fiber-tracheids. The fiber-tracheids have distinct cell contents and are, therefore, living cells. In a sense they take the place of xylem parenchyma, which does not occur in the root (Pl. LI, fig. 18).

In macerated tissue the nonlignified fiber-tracheids are seen to be narrow and sharp pointed. Some measure .252 x .011 mm., and are therefore 23 times longer than wide. The numerous pits in the large tracheal tubes are heavily bordered and arranged in relatively straight rows. Tracheal tubes are more numerous than any other elements in the xylem tissue. The small, pitted, lignified tracheids, measuring .013 x .038 mm., have blunt pointed ends.

Crystals also occur in the tracheal tubes of the root. They are large and simple, but very irregularly formed. In one microscopic field five or six crystals have been counted.

In the same cross section (1.056 mm. in diameter) the cortical tissue measures .189 mm. in width. There are eleven or twelve rows of parenchyma, the outer layers being only slightly compressed or torn. The endodermis is not definite, but the two or more inner rows of cells have rather thickened walls and measure about .041 by .018 mm. in diameter, the longer axis running tangentially. In longitudinal sections, all cortical cells are somewhat elongated and many are two times as long as they are broad.

As is the case in the phloëm of the stem, the sieve tubes and companion cells are very small and are massed in small clumps at regular intervals. Two or three rows of thin-walled phloëm parenchyma cells flank these clumps exteriorly and complete a phloëm cylinder which measures .073 in diameter (Pl. LI, fig. 19).

SUMMARY

A series of anomolies of growth and structure is to be found in members of the families Chenopodiaceæ, Aizoaceæ, Phytoloccaceæ, Nyctaginaceæ, and their well-known congeners. Successive rings of distinct vascular bundles appear in the stems and even in the root and bring about secondary thickening. An intermediate or interfascicular tissue separates the zones of growth (De Bary, 1884). Some species of these families, however, have normal growth, for example *Rivina brasilienses* and *R. aurantiaca* among the Phytolaccaceæ. With these *M. verticillata* can be classed, for the root and stem, while they show some peculiarities, are not anomolous in the above sense.

Both stem and root of *Mollugo,* at least in the older portions, appear to have annual rings. In the stem the amount of tissue, as well as the structure, varies between nodes and internodes, the cortical parenchyma being nearly twice as thick at the nodes. The bast fibers at internodes appear as a broken irregular cylinder, 1 or 2 cell layers in thickness. At internodes it forms a more prominent cylinder with an undulating margin which varies from 1 to 6 cells in thickness, although gaps occur here and there. There are no medullary rays. Other tissues of the stem are relatively normal.

In the pseudoannual rings of the root, the zones of tracheal tubes are separated from each other by rows of lignified tracheids. The units which form the tracheal tubes are heavily pitted, and sharp remnants of the cross walls remain. Between the tracheal tubes are groups of nonlignified fiber-tracheids which remain alive and evidently substitute for xylem parenchyma.

Simple and compound crystals of calcium oxalate are abundant in the mesophyll tissue of the leaf, in the cortical tissue of the stem, and are found, not infrequently, in xylem tubes of root and stem. Crystal sand occurs in a few of the epidermal cells. The myriad minute crystals in the mesophyll generally have definite shape.

Anatomical modifications, probably held in common with more highly specialized xerophytic ancestors, are found in the thickened leaf whose middle portion is occupied by water-storing parenchyma cells, and in the vestigial trichome-bases which occur among the typical sinuous epidermal cells.

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PLATE XLVIII

(FREE-HAND AND PROJECTION DRAWINGS OF *Mollugo verticillata* L.)

FIG. 1. Seed from mature ovary.

FIG. 2. Seed with testa removed, showing contained embryo and endosperm material.

FIG. 3. Old flower, carpels and central placenta, etc.

FIG. 4. Mature flower, sepals reflexed to show stamen.

FIG. 5. Epidermis from stem (× 185).

FIG. 6. Mollugo verticillata L.

FIG. 7. Mesophyll cells—crystal sacs (× 185).

FIG. 8. Sclerenchyma cells from stem. Macerated tissue (× 185).

FIG. 9. Mesophyll cells adjacent to large vein (× 160).

FIG. 10. Venation of leaf tip (× 140).

FIG. 11. Upper epidermis (× 185).

FIG. 12. Epidermis over midrib (× 185).

FIG. 13. Upper epidermis, cross section, upper wall cutinized (×-160).

FIG. 14. Probable vestigial epidermal base of trichome (× 185).

FIG. 15. Lower epidermis. Cross section through stoma (× 160).

FIG. 16. Lower epidermal cells (× 185).

PLATE XLVIII

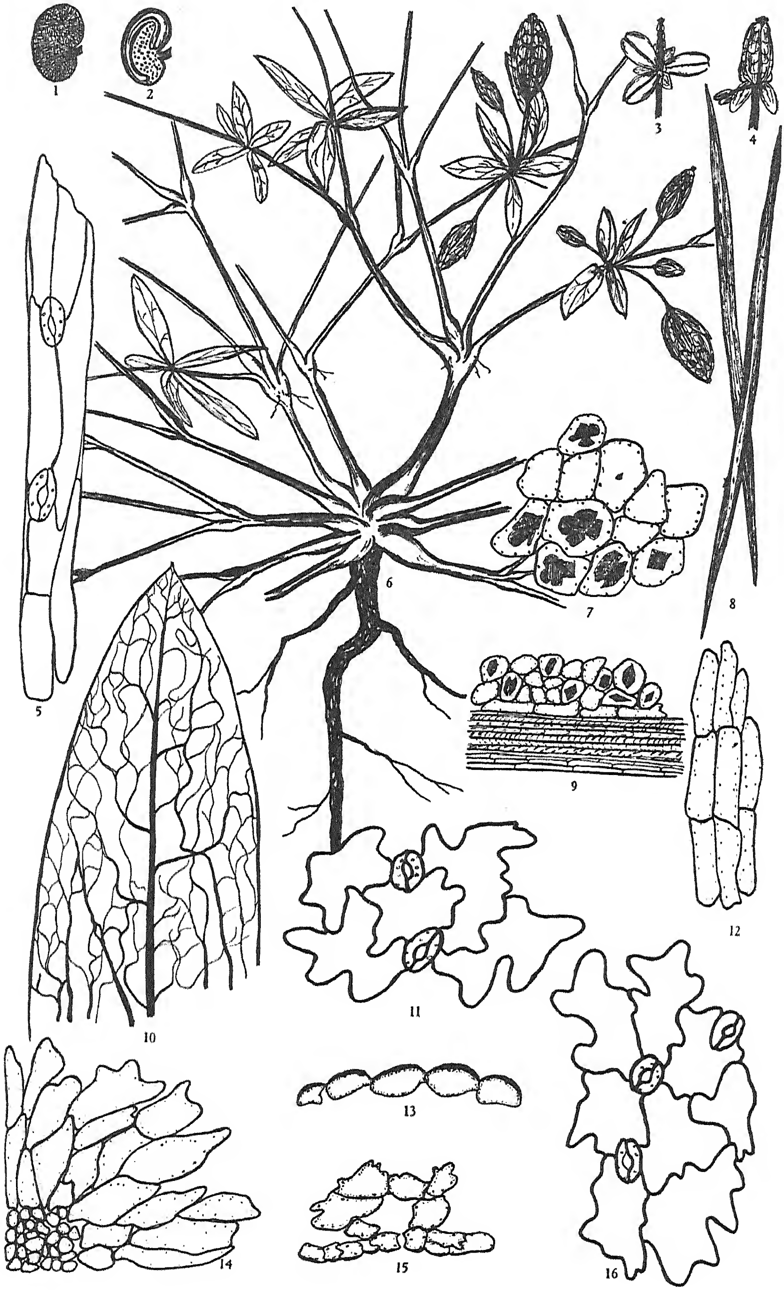


PLATE XLIX

(Photomicrographs of Stem)

FIG. 1. Cross section of stem through region of node, second from starting point (× 22).

FIG. 2. Cross section of stem just above node. Note abundant cortical tissue (× 22).

FIG. 3. Cross section through node, showing traces of three lateral branches (× 22).

FIG. 4. Cross section of stem from 4th internode (× 39).

FIG. 5. Cross section of stem at node, showing broken bast fiber ring (× 105).

FIG. 6. Portion of Fig. 4 more highly magnified. Bast fibers 5 to 6 rows deep (× 95).

FIG. 7. Cross section through large stem at internode. Pseudoannual rings evident (× 95).

PLATE XLIX

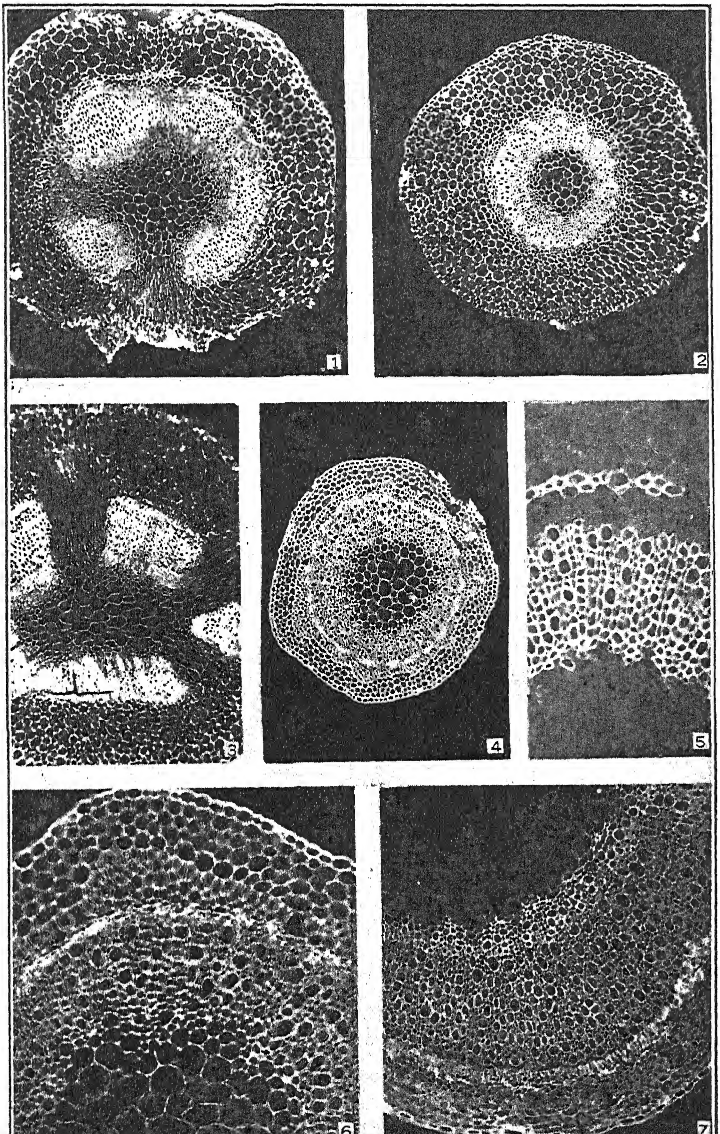


PLATE L

(Photomicrographs of Flower, Leaf, etc.)

FIG. 8. Rosette crystals and simple rhombohedral crystals in tissue of leaf cleared in chloral hydrate (× 126).

FIG. 9. Longitudinal section through flower. Central placenta, short style, seeds in carpels, etc. The outer seed coat is becoming cutinized (× 60).

FIG. 10. Cross section of flower showing loci and arrangement of sepals, carpels, placentæ, etc. (× 80).

FIG. 11. Upper third of leaf showing crystals in the cortical tissue (× 112). Cross section of petiole.

FIG. 12. Cross section of leaf. Note thickness due to water-storage parenchyma, and depression over midrib (× 115).

PLATE L

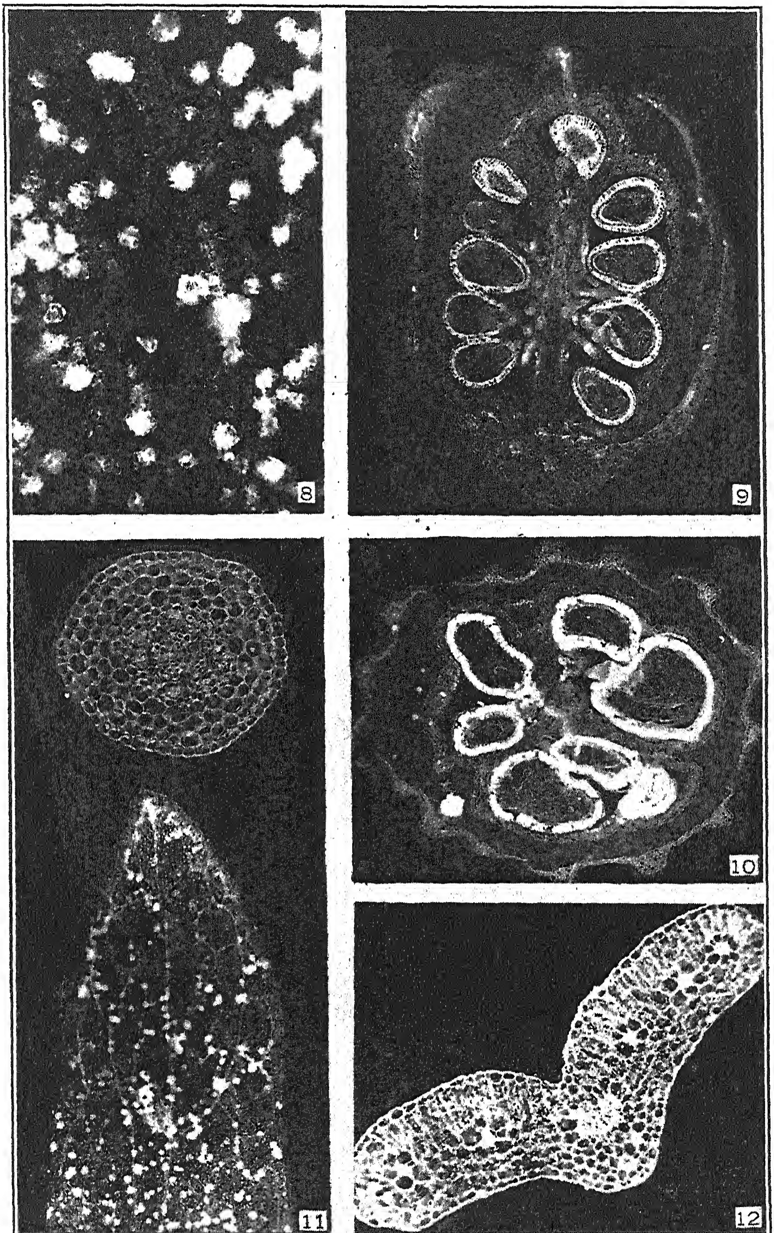


PLATE LI

(Photomicrographs of Tissues of Stem, Root, etc.)

FIG. 13. Longitudinal section through phloëm and cortical tissue. Sieve tube is four cells removed from the cortex (× 372).

FIG. 14. Longitudinal section through protoxylem and metaxylem of stem (internode, × 372).

FIG. 15. Longitudinal section of stem showing crystal sand in xylem duct (× 89).

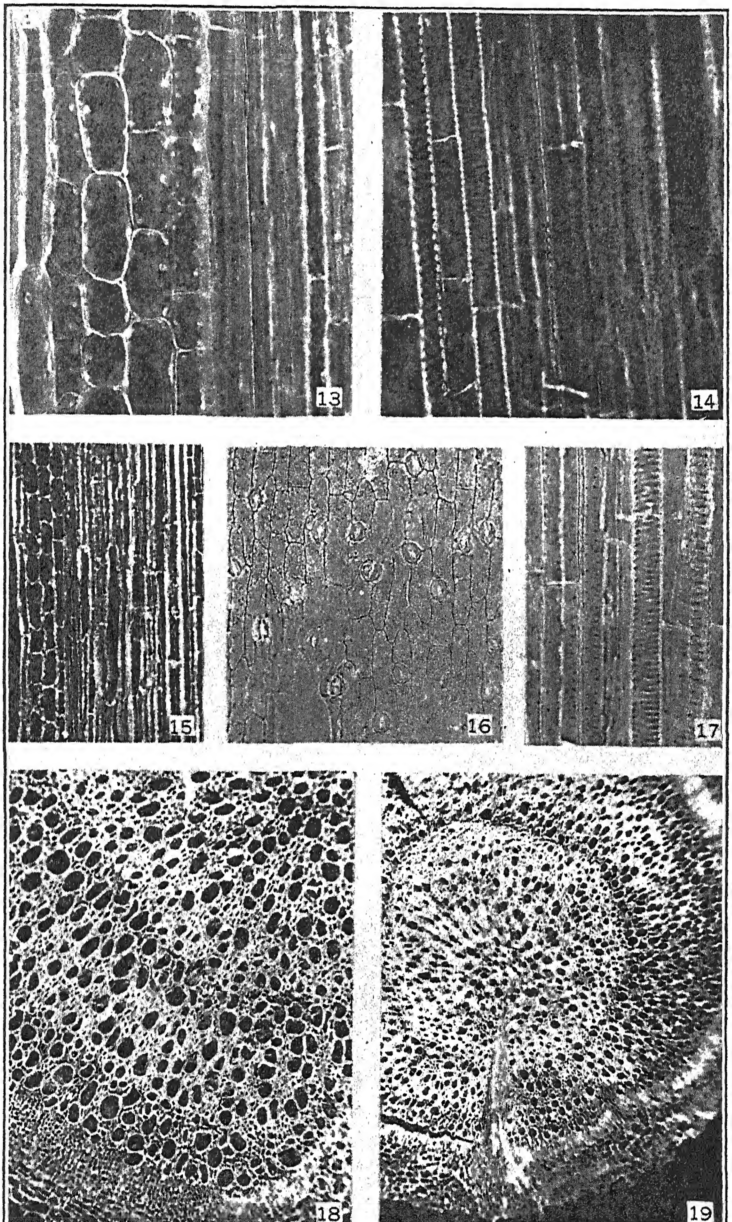
FIG. 16. Stomata in epidermis of stem (×120).

FIG. 17. Bordered pits in the walls of tracheal tube and adjacent tracheids (× 372).

FIG. 18. Cross section of large root showing pseudoannual rings, etc. (× 130).

FIG. 19. Cross section of root showing origin of secondary rootlet (× 130).

PLATE LI



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Morphology and Anatomy of *Lygodesmia juncea* (Pursh) D. Don.

LIZA SPANN

ABSTRACT: *Lygodesmia juncea* (Pursh) D. Don., a Compositæ, has small leaves. Stomata occur on both surfaces. The stomata of the aboveground stem are almost as numerous as those of the leaf. The aboveground stem has a palisade chlorenchyma which is significant in photosynthesis.

The tissue organization of the aboveground stem, underground stem and root are discussed. Laticiferous tubes traverse the length of the plant as a continuous anastomosing system occurring in the phloëm and pericycle. An outstanding characteristic of this plant is that the leaf trace has two origins: (*a*) the part which forms the midrib of the leaf is derived from a bundle of protoxylem tubes which swing sharply out and pass directly into the leaf; (*b*) the part which forms the primary veins parallel to the midrib is derived from protoxylem tubes that come out from the xylem cylinder considerably below the leaf insertion.

Resin is found in the laticiferous tubes, parenchyma cells of leaf, cortex of the stem and tracheal tubes of the root. Glucose is present throughout, but is most abundant in the leaf and aboveground stem. A glucoside, lygodesmin, occurs in the root, stem and leaf. Saccharose is present only in the aboveground stem and leaf.

Various points in the paper are illustrated with thirty-one projection drawings and fourteen photomicrographs.

CLASSIFICATION AND DISTRIBUTION

LYGODESMIA *juncea* (Pursh) D. Don. belongs to the Chichoriæ tribe of the Compositæ. According to Gray (1908) Lygodesmia is derived from two Greek words, *lugos*, a pliant twig, and *desme*, a bundle, from the fascicled twiggy or rushlike stems. *L. juncea* is the type species of the genus. Britton and Brown (1913) relate that about six species are natives of western and southern North America, but they describe only two species, *L. juncea* (Pursh) D. Don. and *L. rostrata* Gray, the former inhabiting the plains from

28—3482

Minnesota to Saskatchewan, Wisconsin, Missouri, Nebraska and Arizona and the latter occurring on plains and in canyons from South Dakota to Saskatchewan, Nebraska, Kansas, Colorado and Wyoming.

Coulter and Nelson (1909) give four species: *L. grandiflora* T. & G., *L. Spinosa* Nutt. and the two above-mentioned species. They say that *L. spinosa* is distributed on gravelly hills and plains from eastern Oregon to California, Nevada and Idaho, and that *L. grandiflora* is distributed on gravelly hills in Wyoming and Colorado to Utah.

Chapman (1897) mentions only one species, *L. aphylla* D C., as occurring in the southern United States, specifically on dry, sandy pine barrens in Georgia and Florida.

HABITAT AND GENERAL MORPHOLOGY

Lygodesmia juncea grows in sandy soils on hills that are exposed to the sun and on sandy plains. The particular plant upon which this work is based was collected by Prof. W. C. Stevens in August in northeastern Kansas on a bluff near the Missouri river.

This species is a perennial. The stiff, glabrous, striate, much-branched stems are from 2 to 4 dm. high. The diameter of the main branches at their bases is about 2.5 mm. The stem gradually tapers toward the apex, the average diameter there being 0.5 mm. The average length of the internodes is 2 cm.

The leaves are rigid, sessile and opposite. The lower leaves are acutely linear-lanceolate and entire. The average width of the basal leaves is 3.5 mm. and the average length is 4.5 cm. The upper leaves are smaller, averaging 0.5 mm. in width at the base and 2 mm. in length, or they may be reduced to subulate scales.

The underground stem extends to a considerable depth below the surface. Its diameter ranges from 2 to 3 mm. The internodes are about 2.5 cm. in length. At the nodes are opposite, scale-like leaves which average 4 mm. in width at the base and 7 mm. in length. The scale gradually tapers, forming an acute apex.

MATERIALS AND METHOD

Several methods of procedure were followed in preparing the tissue for microscopic examination. The specimen had been preserved in thirty per cent alcohol. Small pieces of the stem, root and leaf were dehydrated and embedded in paraffin by the N-butyl alcohol method of Zirkle (1930) and then cut in cross and longitudinal sections varying from ten to forty microns in thickness. The leaves and some of the stem sections were cleared in chloral hydrate.

Three reagents were used for the kinds of cell walls: Sudan III for cutinized and suberized walls, chloroiodide of zinc for cellulose walls, and phloroglucin and hydrochloric acid for lignified walls. For cell contents Fehling's solution was used for glucose, and sulphuric acid and Fehling's solution for glucosides. Czapek (1897) and Hoffmeister's (1898) invertase method was used for saccharose. To distinguish between fats and resins the saponification test of Moenikes (1924) was run and several solvents, such as alcohol and carbon disulphide, were used.

Sections for photomicrographs were dehydrated and cleared in toluol, and then mounted in hyrax. Exposures varying from fifteen seconds to three minutes with an arc light illuminant were made on hard-surfaced sensitized paper, giving a negative print. The drawings were made with an arc-light projectoscope.

ABOVEGROUND STEM

The stem has two kinds of epidermal cells. Those over the bast fibers are vertically elongated and rectangular with regular margins and have no stomata (Pl. LII, fig. 1), while those over the chlorenchyma are relatively large with irregular margins and have stomata. The outer cell wall of the epidermis, as seen in cross section, is slightly convex, and the inner wall is flat. The radial diameters of the cells average 0.02 mm. and the tangential diameters vary from 0.025 mm. to 0.05 mm., the shortest cells being in front of the bast fibers. The epidermis has a thin cuticle and the outer cell walls are cutinized about half across. These walls are 0.006 mm. thick, but the inner and radial walls are thinner and are cellulose throughout. The average number of stomata per sq. mm. over the entire surface of the stem is thirty. In areas between the bast fibers the average is forty-five per sq. mm.

The parenchyma of the cortex is in the form of palisade chlorenchyma (Pl. LII, fig. 15), three to four cell layers thick, the diameters of the cells averaging 0.016 mm. tangentially and 0.039 radially. The walls are cellulose and very thin. Along with chloroplasts are droplets of resin. Bundles of bast fibers alternate with patches of chlorenchyma of the cortex (Pl. LIV, fig. 2). The bast fibers are lignified and are 0.007 mm. thick and from 2 to 2.5 mm. long (Pl. LII, fig. 3).

Beneath the chlorenchyma of the cortex is a definite endodermis (Pl. LV, figs. 3 and 4, and Pl. LIV, fig. 2) whose cells have radial diameters of 0.017 to 0.025 mm. and tangential diameters averaging

0.04 mm. The walls are cellulose and are 0.002 mm. thick. The endodermis contains droplets of resin (Pl. LII, fig. 19).

Bast fibers also occur in the pericycle just beneath the bundle of bast fibers in the cortex (Pl. LIV, fig. 2). These are thicker walled than those of the cortex.

According to Col (1904) the secreting system is found existing in three distinct forms in the Compositæ: (1) anastomosing latex tubules, (2) secreting canals, and (3) cells secreting latex. The form existing in this stem is of the first type. The tubes form a much-branched anastomosing system throughout the phloëm and pericycle (Pl. LIII, fig. 9) and contain a resinous secretion.

The vascular tissue is in the form of a cylinder surrounding a relatively large pith. The phloëm elements are very minute with correspondingly thin walls. The parenchyma cells are isodiametric in cross section, having an average diameter of 0.013 mm. The sieve tubes give a distinct protein reaction.

The xylem cylinder is composed of two distinct parts (Pl. LIV, fig. 2): that part which contains the protoxylem points and is relatively broad radially, having protoxylem, metaxylem and secondary xylem, is made up of tracheal tubes, xylem parenchyma, and fiber-tracheids; and that part which is radially narrow, embracing metaxylem and secondary xylem only, is made up of xylem parenchyma cells (Pl. LIII, fig. 3) which are 0.08 mm. long and 0.02 mm. wide in longitudinal section, and fiber-tracheids which are 0.2 mm. long and 0.01 mm. wide. The tracheal tubes have thick, pitted, lignified walls (Pl. LIV, fig. 3) and have an average diameter of 0.058 mm. The protoxylem tubes average 0.016 mm. in diameter.

The leaf traces have two origins. Those vascular elements which form the midrib of the leaf come from the primary xylem and are composed of protoxylem only (Pl. LIII, fig. 2). These bundles of protoxylem pass up the stem and make an abrupt turn out into the leaf, while those which enter the leaf on either side of the midrib pass out from the xylem considerably below the leaf insertion, travel up the stem just under the phloëm, then, passing out through the phloëm and pericycle, ascend beneath the endodermis (Pl. LIII, fig. 5) and finally pass out into the sessile leaf and continue on either side of the midrib about two-thirds the length of the leaf. In Plate LIII, figure 1 the relation of the two origins of the leaf traces are represented.

The spiral tubes of the traces on either side of the midrib have an average diameter of 0.011 mm. They are found in cross sections

of stems just beneath the phloëm, in the phloëm and pericycle, and just beneath the endodermis, singly or in bundles of from two to four strands.

The parenchyma cells of the pith are smaller near the periphery and larger near the center. The cell walls are slightly lignified. The cells are isodiametric in cross section, and their diameters vary from 0.09 to 0.16 mm. This part of the stem contains glucose, saccharose and a glucoside which we have called lygodesmin.

The stem is infested by an insect larva which causes a globose gall varying from 5 mm. to 8 mm. in diameter. The galls are in groups of from two to ten on one side of the stem. The epidermal cells (Pl. LIV, fig. 4) of the gall are similar to those of the normal stem, but smaller, and the outer cutinized walls thinner. Beneath the epidermis of the gall is a layer of chlorenchyma containing chloroplasts and resin. This layer is thinner than the corresponding layer of the stem and contains no bast fibers. Just beneath the rather indistinct endodermis in the parenchyma of the pericycle there is a system of anastomosing latex tubes filled with resinous material. These tubes seem to be scattered promiscuously through the gall, following the vascular system until they reach the tissue surrounding the insect larva. Here they form a network around the entire cavity. The vascular system in cross section is arranged in bundles near the periphery, which run in various directions through the stele. The bulk of the gall has been formed by the proliferation of the parenchyma cells of the stele, which are smaller than the corresponding cells of the stem. The cell walls of the outer layer of pith cells are lignified, but the inner layers of cells have cellulose walls. The inner cells are broken down, forming a cavity in which the insect resides. Küster (1911), the eminent authority on galls, does not mention this one.

LEAF

The leaf is parallel veined (Pl. LII, fig. 11) with anastomoses between the veins. In surface view the upper and lower epidermal cells of the leaf vary in size and shape, but have almost even margins (Pl. LII, figs. 7 and 9). The epidermal cells over the midrib and veins are elongated, rectangular cells with regular boundaries (Pl. LIV, figs. 7 and 8). In cross section the cells of the upper and lower epidermis are about the same size, averaging 0.03 mm. in tangential diameter and 0.026 mm. in radial diameter. The outer walls of both are partly cutinized, but those of the lower epidermis are

slightly thicker than those of the upper (Pl. LII, figs. 13 and 18). The radial walls are thinner than the outer walls and the inner walls are the thinnest.

Stomata occur on both surfaces of the leaf. The openings are elongate-elliptical in outline and measure 0.02 mm. in length. The stomata are only slightly more numerous on the lower epidermis than on the upper, averaging 53 per sq. mm. on the lower and 51 per sq. mm. on the upper.

Just beneath the lower epidermis is one row of interrupted isodiametric collenchyma cells. These cells also occur at the margins of the leaf and are especially prominent beneath the midrib and primary veins (Pl. LV, fig. 1). The palisade cells are on each side of the leaf in two-cell layers. The cells are about three times as long as broad and, in addition to the chloroplasts, contain frequent droplets of resin.

The parenchyma sheath of the veins contains resin, and besides functioning in connecting the vascular system with the other tissues it has a considerable water-storage capacity.

The laticiferous tubes (Pl. LIII, fig. 7) follow the veins outside of the parenchyma sheath and form a network between the veins. De Bary (1884) states that in the ribs of leaves the main trunks of latex tubes lie chiefly in the tissue bordering the phloëm portions of the vascular bundles, following the longitudinal course of the latter, and as seen in cross section are scattered without strict regularity among the surrounding parenchyma. This is correct for this leaf. As in the stem, the tubes are filled with resinous material. Glucose, a glucoside, an abundance of saccharose, and resin are found in the leaf.

UNDERGROUND STEM

The outer cell walls of the epidermis are cutinized and thinner than the corresponding cell walls of the aboveground stem. In cross section the radial and tangential diameters of these cells measure about the same, being about 0.02 mm. There is one row of collenchyma cells just beneath the epidermis (Pl. LII, fig. 17), which is the only strengthening tissue of the cortex.

The cortex, excluding the collenchyma, is made up of about nine layers of parenchyma cells with lignified walls (seen in cross section in Pl. LIV, fig. 1, and in longitudinal section Pl. LV, fig. 5). The diameters of the cells vary from 0.033 to 0.05 mm., the smaller ones being near the periphery. Following this are three layers of cork cells (Pl. LV, fig. 5) which have originated from the cells of the

pericycle. The tangential diameter of these cells is 0.03 mm. and the radial diameter is 0.012 mm. The cell walls are suberized.

The parenchyma cells of the pericycle have thin cellulose walls. The latex tubes (Pl. LIII, fig. 8) form a richly anastomosing system extending out into the pericycle, but are more numerous in the phloëm. The phloëm is otherwise composed of phloëm parenchyma and sieve tubes.

The xylem tissues form a continuous cylinder around the pith (Pl. LIV, fig. 1). The cylinder is composed of two parts, as in the aboveground stem: metaxylem parenchyma cells and fiber tracheids alternating with groups of metaxylem subtended by the protoxylem. The parenchyma cells of the pith in cross section are large, isodiametric cells with lignified walls.

The anomalous protoxylem tubes are also found in the underground stem, coming out from the xylem, traveling up the stem just outside the xylem cylinder, crossing through the phloëm and pericycle, and up the stem under the cork cells.

The glucoside, lygodesmin, is abundant in the parenchyma cells of the cortex. Glucose is not as abundant as in the leaves and aboveground stem, and saccharose is not present.

ROOT

In the root section shown in Plate LIV, figure 5, cork cells have been formed and have cut off all the cells outside the pericycle. The cell walls of this tissue are thin and suberized. In cross section the cells have a radial diameter of 0.02 mm. and a tangential diameter of 0.05 mm.

Beneath the cork cells are parenchyma cells of the pericycle with thin, cellulose walls. The latex tubes form a network (Pl. LII, fig. 4) extending out into this layer of cells and into the phloëm, being more numerous in the phloëm. According to Col (1904) the laticiferous tubes in the Compositæ are always situated in the pericycle of the stem, in the primary phloëm of the root, and in the secondary phloëm of both these organs. This plant is an exception in that the laticiferous tubes occur in the pericycle and phloëm of both the root and stem. Moenikes' (1924) statement that in all the compositæ no mucilage is laid down in the secretion passages is not contradicted by this plant.

The xylem tissues of the root are divided into wedges by rays which vary from one to three cells across tangentially (Pl. LIV, fig. 5). The ray cells (Pl. LIII, fig. 6) are about twice as long radially as

tangentially. They have thin cellulose walls. The diameters of the tracheal tubes are larger than those of the stem (Pl. LII, figs. 5 and 6), varying from 0.033 mm. to 0.083 mm. Some of the tracheal tubes next to the phloëm are filled with resinous material (Pl. LII, fig. 16) similar to that in the latex tubes. The protoxylem elements have a rather compact spiral and are about the same size as those of the stem. Between the tracheal tubes throughout the xylem are parenchyma cells and fiber tracheids. The anomalous protoxylem tubes are found occasionally in the root in the pericycle just beneath the cork cells. Glucose and a glucoside are present in the root, but no saccharose was found.

SUMMARY

Lygodesmia juncea (Pursh) D. Don., a member of the Compositæ, is a rush-like perennial about 4 dm. high. There are six species of this genus native of the United States.

The upper and lower epidermis of the leaf and the epidermis of the aboveground stem are very much alike, having alternating longitudinal rows of irregular cells with stomata and of rectangular cells without stomata, the latter overlying and underlying the main veins. Again, the parenchyma cells of the cortex of the stem are similar to the parenchyma cells of the leaf in character of walls, shape, chloroplasts, and resin content.

The stem above ground is the only part of the plant that has bast fibers, which occur in the cortex and pericycle. The stem is infested by an insect larva which causes a globose gall.

Laticiferous tubes traverse the entire body of the plant as a continuous anastomosing system occurring in the phloëm and pericycle. The tubes are filled with resinous material.

As to cell contents, resin is the most abundant material, since it is found in the laticiferous tubes of all organs of the plant, in the parenchyma cells of the leaf, the cortex of the stem, and the tracheal tubes of the root. Glucose is present in all the organs, but is most abundant in the leaf and in the aboveground stem. A glucoside, lygodesmin, occurs in all of the organs. Saccharose is present only in the aboveground stem and in the leaf, being most abundant in the leaf. The phloëm contains protein.

The outstanding characteristic of this plant is that the leaf trace has two origins: (1) a part which forms the midrib is derived from a bundle which separates from the vascular system of the stem and swings abruptly outward into the leaf, and (2) a part which forms

the primary veins parallel to the midrib, the tracheal elements of these veins being protoxylem tubes which separate from the vascular cylinder of the stem considerably below the leaf insertion, pass up the stem outside the xylem cylinder, cross through the phloëm and pericycle, ascend the stem beneath the endodermis for some distance, and then pass out into the leaf.

In conclusion, the writer wishes to express her appreciation to Prof. W. C. Stevens for his suggestions, helpful criticisms and advice during the entire progress of this investigation.

PLATE LII

PROJECTION DRAWINGS OF *Lygodesmia juncea* (Pursh) D. Don.

FIG. 1. Epidermis of the aboveground stem (× 140).

FIG. 2. Cross section of the pith cells of the aboveground stem (× 140).

FIG. 3. Bast fiber from the aboveground stem (× 40).

FIG. 4. Laticiferous tubes of the root (× 40).

FIG. 5. Elements from metaxylem and protoxylem of the root (× 140).

FIG. 6. Elements from metaxylem and protoxylem of the aboveground stem (× 140).

FIG. 7. Upper epidermis of the leaf (× 140).

FIG. 8. Longitudinal section of the pith cells of the aboveground stem (× 140).

FIG. 9. Lower epidermis of the leaf (× 140).

FIG. 10. Tip of the leaf (× 8).

FIG. 11. Base of the leaf, showing parallel veins (× 8).

FIG. 12. Cross section of the cork cells of the root (× 140).

FIG. 13. Cross section of the upper epidermis of the leaf, showing a stoma (× 140).

FIG. 14. Cross section of the metaxylem tracheal tubes of the root (× 140).

FIG. 15. Cross section of the parenchyma cells of the cortex of the aboveground stem (× 185).

FIG. 16. Semidiagrammatic drawing from the cross section of the root, showing some xylem tubes filled with resin (× 17).

FIG. 17. Cross section of the epidermis and collenchyma of the underground stem (× 185).

FIG. 18. Cross section of the lower epidermis of a leaf, showing a stoma (× 140).

FIG. 19. Cross section of the endodermis of the aboveground stem, showing resin in the cells (× 185).

FIG. 20. Cross section of the parenchyma cells of the cortex of the underground stem (× 185).

FIG. 21. Cross section of cork cells of the underground stem (× 140).

FIG. 22. Cross section of a bundle of bast fibers from the aboveground stem (× 140).

PLATE LII

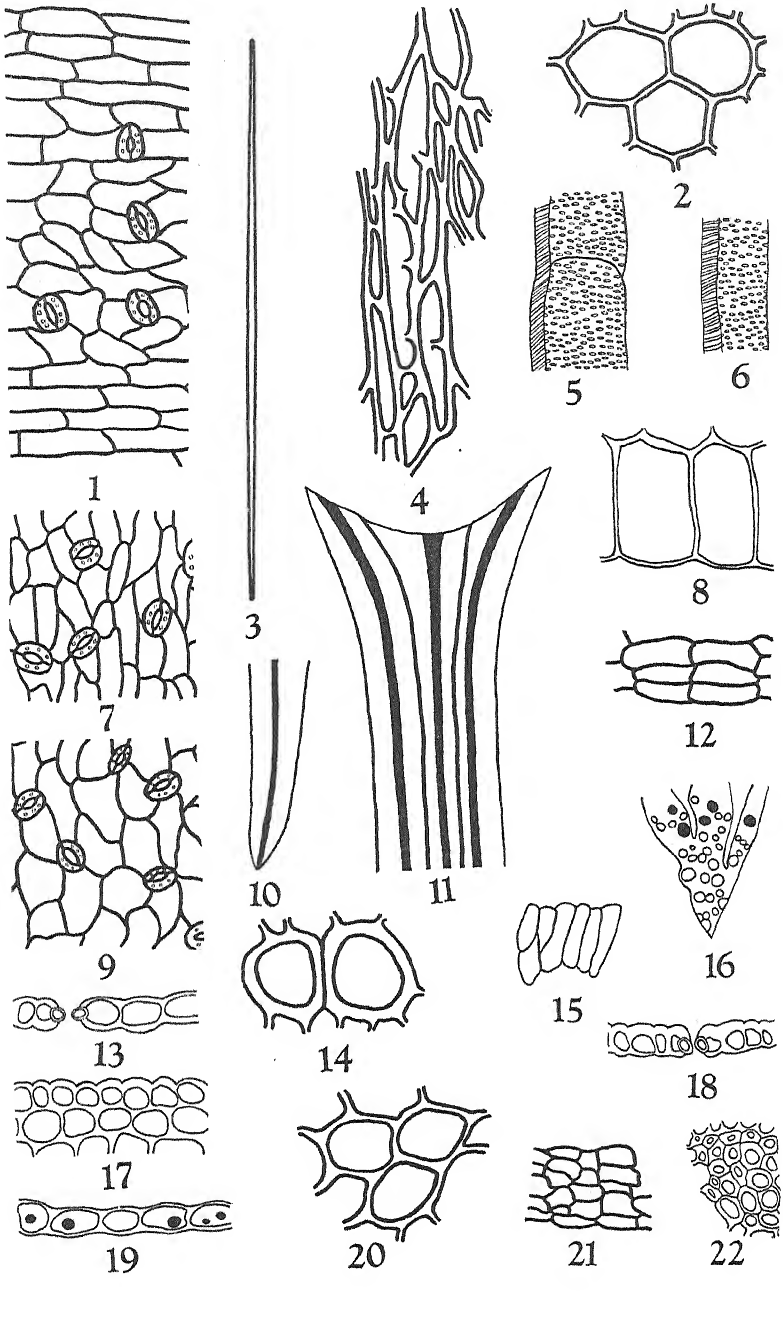


PLATE LIII

PROJECTION DRAWINGS

FIG. 1. Semidiagrammatic drawing of a cross section of the aboveground stem, showing a leaf gap, midrib trace, and protoxylem tubes passing out of the pericycle to enter veins parallel to the midrib ($\times$ 8).

FIG. 2. Semidiagrammatic drawing of the longitudinal section of the aboveground stem showing a leaf and branch gap, a midrib trace, and protoxylem tube in the pericycle ($\times$ 16).

FIG. 3. Longitudinal section of xylem parenchyma cells of the aboveground stem ($\times$ 140).

FIG. 4. Longitudinal section of the pith cells of the underground stem ($\times$ 185).

FIG. 5. Semidiagrammatic drawing of the longitudinal section of the aboveground stem showing a protoxylem tube which contributes to a vein parallel to the midrib, passing through the xylem, the phloëm, and the pericycle, and up the stem under the endodermis ($\times$ 120).

FIG. 6. Cross section of the ray cells of the root ($\times$ 185).

FIG. 7. Laticiferous tubes of the leaf ($\times$ 40).

FIG. 8. Laticiferous tubes of the underground stem ($\times$ 40).

FIG. 9. Laticiferous tubes of the aboveground stem ($\times$ 40). In the semidiagrammatic drawings 1, 2 and 5 the xylem is shaded with parallel lines, the phloëm and pericycle are stippled, midrib trace is cross-hatched, and the protoxylem tubes are solid black.

PLATE LIII

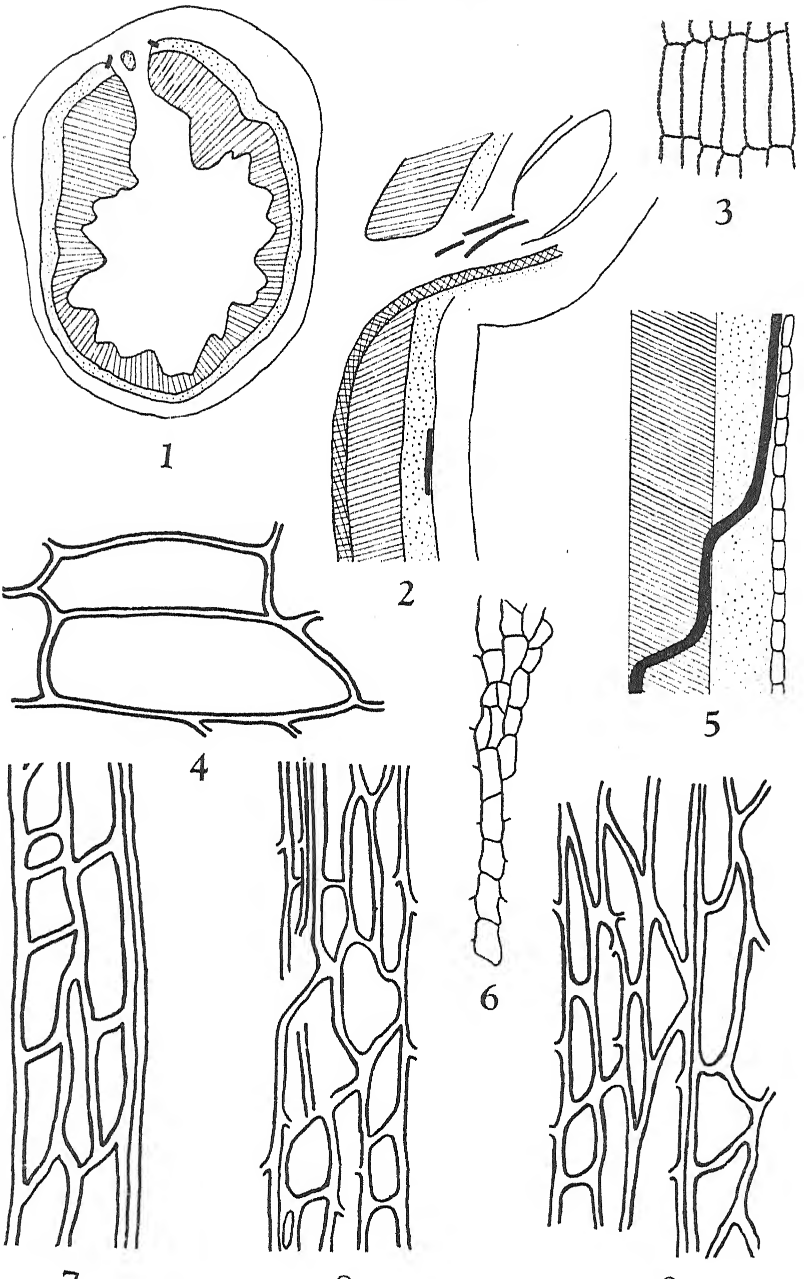


PLATE LIV

PHOTOMICROGRAPHS OF ROOT AND STEM SECTIONS AND EPIDERMIS

FIG. 1. Cross section of the underground stem ($\times$ 30).

FIG. 2. Cross section of the aboveground stem ($\times$ 30).

FIG. 3. Longitudinal section of the aboveground stem, showing the pith, protoxylem, and metaxylem ($\times$ 105).

FIG. 4. Cross section of a gall ($\times$ 30).

FIG. 5. Cross section of root ($\times$ 25).

FIG. 6. Epidermis of the aboveground stem ($\times$ 30).

FIG. 7. Lower epidermis of the leaf ($\times$ 30).

FIG. 8. Upper epidermis of the leaf ($\times$ 30).

PLATE LIV

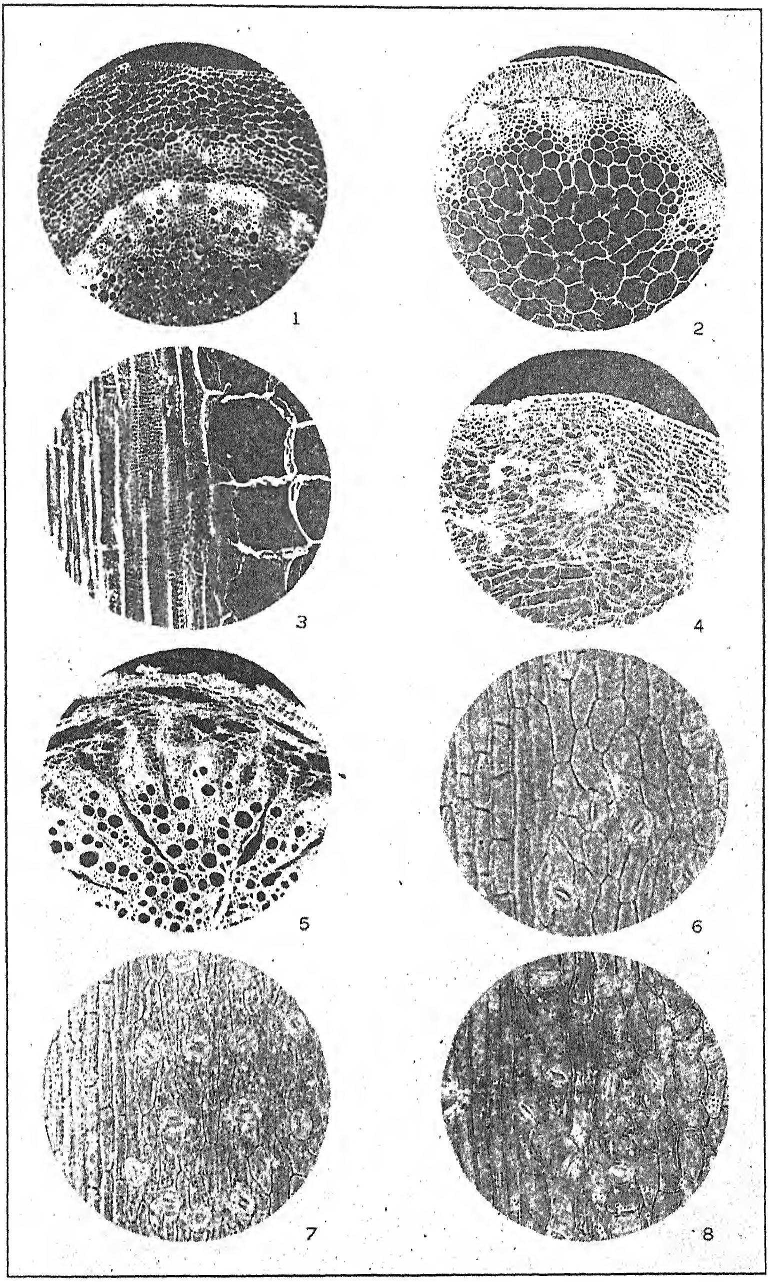


PLATE LV

PHOTOMICROGRAPHS OF LEAF AND STEM SECTIONS

FIG. 1. Cross section of a leaf (× 30).

FIG. 2. Cross section of a leaf, showing a stoma in the lower epidermis (× 105).

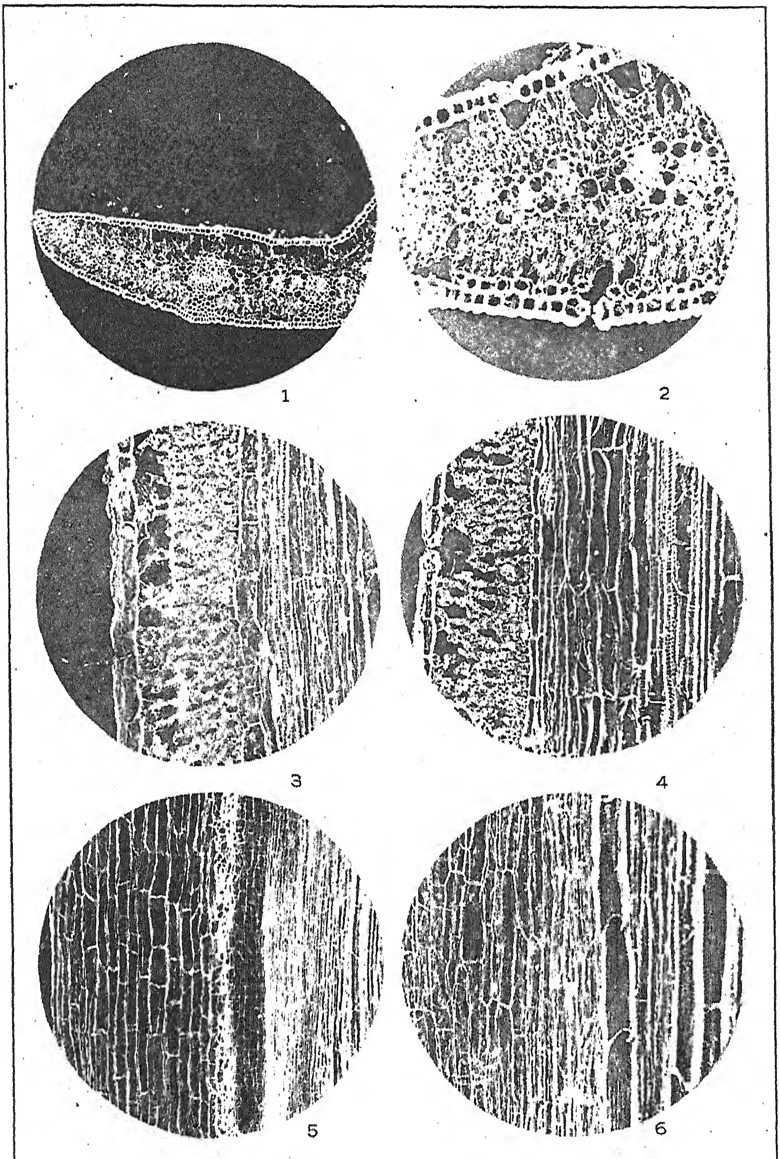
FIG. 3. Longitudinal section of aboveground stem, showing the protoxylem tubes just beneath the endodermis (× 105).

FIG. 4. Longitudinal section of the aboveground stem, showing a stoma, chlorenchyma, endodermis, one or two rows of pericycle cells, and protoxylem tubes just inside the phloëm (× 105).

FIG. 5. Longitudinal section of underground stem (× 30).

FIG. 6. Longitudinal section of the underground stem, showing the phloëm and metaxylem (× 105).

PLATE LV



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Comparative Anatomy of *Mentzelia oligosperma* and *M. decapetala*

(Contribution from the Botanical Laboratories of the University of Kansas)

W. E. BOOTH

ABSTRACT: The gross morphology of the two species and detailed account of their microscopic anatomy are given. Microchemical tests are reported showing the kinds of cell walls and cell contents. The principal anatomical differences between the two species are pointed out. The two species are shown to be alike in the origin of the phellogen of stem and root, growth in diameter of pericycle of root and stem, silicified trichomes, predominance of wood fibers in the xylem, and in fatty oils and proteins in the endosperm of seeds. The species are shown to differ in stored corbohydrates—starch in *oligosperma,* glucosides in *decapetala*—in the presence of palisade cells in the cotyledons of *oligosperma* and their absence in *decapetala,* in the smaller average of cell size in *oligosperma,* and in unlike character of stone cells of the seed testas. The paper is illustrated by plates embracing thirty-two drawings, fifteen photomicrographs and two habit photographs.

GEOGRAPHICAL DISTRIBUTION

Mentzelia oligosperma Nutt, *Mentzelia decapetala* (Pursh) Urban and Gelg.

MENTZELIA is a member of a comparatively small family, Loasaceæ, which is characterized particularly by stinging or barbed hairs, and a flower structure similar to that of the cacti. This genus is the only representative of its family found in this region (4), except for species formed by a division of the above species (5).

Mentzelia was named by Linnæus in 1753 for Mentzel, a German botanist (1). Only two species of *Mentzelia* are known to be in our range (Kansas), but twelve species are described for the Central Rocky Mountain region (2), and thirty-four in that part of the United States north of New Mexico (3).

Collections of *M. oligosperma* were made by Prof. W. C. Stevens and by the author from a limestone bluff (Botany Bluff) located five and one-half miles northeast of Lawrence. The presence of this plant is quite uncommon except on limestone banks or talus slopes, where it may be found in some abundance. The specimen of *M. decapetala* used in this study was collected during August by Professor Stevens in Barber county, Kansas. Its habitat was that of a gently rolling xeric prairie.

The distribution of *M. oligosperma* is primarily that of the great plains region. Throughout this region it may truly be classified as a xerophyte. In the eastern extremity it inhabits rocky banks, growing side by side with typical mesophytic plants, but its habit of growth clearly indicates that of a low water requirement.

The range of *M. decapetala* is similar to that of *M. oligosperma.* It does not extend as far east, however, and is found as far north as Saskatchewan. Although the distribution of *M. decapetala* has been described as extending east as far as Iowa (4), no specimens are recorded in the herbarium of the University of Kansas from the eastern part of this state. Its presence is quite evident in the western part of Kansas, and has been found as far east as the central part of the state.

GENERAL MORPHOLOGY

M. oligosperma (stick leaf) grows from 3 to 9 decimeters in height and is highly branched. The type of branching which is quite characteristic of this plant is sometimes described as dichotomous (2). Upon examination, however, it is quite evident that the main axes, 3 to 5 dm. in height, possesses a racemose monopolial system of branching. The further growth in height of this shoot of the first order is arrested by the formation of a single terminal inflorescence. Just below this terminal inflorescence, three lateral branches of equal strength usually arise. These three lateral branches in turn divide repeatedly, presenting an appearance very much like a cymose monopodial inflorescence. The shoots of the second order, however, do not terminate in inflorescens, as it at first appears, but rather give rise to lateral shoots, of the third order, which are of nearly equal strength with fruit in the axes, the shoots of the second order proceeding in an oblique direction. Therefore, those parts of the shoot formed by the triple branching of the main axis also present a true monopodial racemose branching. It is very common to find shoots of the fifteenth order represented on a plant measuring about 6 dm. in height.

The oval-shaped leaves of *M. oligosperma* are comparatively small, with coarsely dentate margins. The lower leaves are short petioled and narrowed at the base. The upper sessile leaves are somewhat broader and have a truncate base. The flowers are composed of five yellow petals, five sepals, many stamens, and an inferior one-celled ovary, which develops into a linear capsule. Capsules collected in this locality showed the number of seeds per capsule not to exceed three; however, plants have been reported with capsules containing nine seeds.

The mode of dehiscence, which is often described as occurring at the summit, is somewhat different from the common type of opening by pores. The tissue which completes the capsule wall at the summit is very different in nature from that below it and upon maturity may fall out, leaving an opening through which seeds might escape. However, tissue at the summit of the capsule does not usually fall out easily, and this is of value in dispersal of the seeds into other localities. The capsule, because of an abcission layer, is easily removed from the plant and may be carried on the coats of animals. Later, due to freezing and thawing or to seed germination, this tissue is loosened and falls out.

The root system is unextensive and much reduced, except for a short, fleshy, primary root. Both primary and secondary roots are often distorted, because of the rocky soil in which they grow, but in general they extend themselves parallel with the surface of the ground in the uphill direction.

M. decapetala is larger than *M. oligosperma* in its parts, but seldom grows to a height of more than six decimeters. The branches, which arise from a woody root, are sparsely branched and often terminate in a flower. The arrangement of leaves on the stem is in spiral fashion, with an approximate two-fifths phyllotaxis. The lower leaves are short petioled and are somewhat lanceolate in shape. The upper leaves are sessile, and as they near the apex of the shoot they are broader and not so long. Hypsophylls are quite numerous below the flowers and are very leaflike in form. In a developmental stage they compare very closely to the same stage of the foliage leaf formation. The deeply cleft margin found in both hypsophylls and foliage leaves remains deeply cleft in the hypsophylls, while the margin of the foliage leaves are widely and coarsely dentate.

Much larger and more conspicuous flowers than obtain in *M. oligosperma* are characteristic of *M. decapetala*. These flowers

regularly open more or less widely in the evening, and are commonly from six to eight centimeters broad. They have five sepals, ten petals, and many stamens. The ovary is inferior and develops into a many-seeded capsule, which dehisces at the summit.

The main root which extends nearly parallel to the surface of the ground in only one direction is common, as is also true of *M. oligosperma*. This root system is probably more extensive than that of *M. oligosperma*, but in form is very similar.

MATERIAL AND METHODS

Specimens upon which this study was based were collected during August and September. In order to prevent excessive wilting the plants were wrapped in moist sphagnum, and, as soon as they reached the laboratory, they were preserved in thirty per cent alcohol.

Microchemical tests were made from material preserved in thirty per cent alcohol. All parts to be sectioned for photographing and for finer study of structure were first desilicified by full-strength hydrofluoric acid for a week; then washed, put through a gradual series of butyl alcohol and embedded in paraffin. The sections to be photomicrographed were mounted in hyrax, and negative prints made on number thirty-one, hard, single-weight photographic paper.

All drawings were made by the aid of a projectoscope from both sectioned and macerated materials.

Standard microchemical tests (6) were used, with few exceptions, in the determination of plant products present. The Czapek inversion test (7) was used in testing for glucocides, and the presence of hemicellulose was demonstrated by dissolving it in a three per cent solution of potassium hydroxide (9).

COMPARATIVE ANATOMY

Within the genus *Mentzelia* very little anatomical research has been published prior to the time of this study. Investigations have been carried on by Gilg in reference to types of epidermal hairs present in the family Loasaceæ, and by Solereder (8), who also describes epidermal hairs and vascular bundles in *M. albescens* and *M. pumila*.

Mentzelia oligosperma

STEM. The epidermis, along with several rows of cortical cells, break away from the stem proper after the formation of a phellogen by the pericycle. This layer of dead tissue sheaths the stem and

presents a grey, shaggy appearance, which is very characteristic (Pl. LVIII, fig. 2). The epidermal cells are in face view somewhat rectangular in shape, but in cross section appear as if crushed. The cell walls are relatively thin, the outer being but slightly thicker than the inner walls. Unicellular epidermal hairs of three general types are regularly present in the epidermis, averaging seven hairs per square millimeter. About 43 per cent of the number present are long, reflex-barbed hairs (Pl. LVI, fig. 1). The barbs are usually in definite rows, and at the apex are five reflexed barbs which in face view appear star-shaped. Forty-three per cent are short hairs, usually without barbs except at the apex (Pl. I, fig. 3). The remaining 14 per cent are long-pointed hairs with barbs which point outward and toward the apex (Pl. LVI, fig. 2). These hairs are often quite long, measuring from .7 to 1.0 millimeter in length. The cell walls of the three types of hairs represented are of strongly silicified cellulose. Around the base of the long-type hairs a single ring of subsidiary cells is commonly present, and these cells are also often silicified (Pl. LVI, fig. 5; Pl. LVIII, fig. 8).

The epidermis and underlying cortical cells, which are not entirely sloughed off, undoubtedly serve as a protection. In addition to this protection a well-formed periderm is present, which develops immediately on the inner side of the pericyclic fibers. Specimens collected early in September had a phellem consisting of not less than two cells in thickness even on the youngest branches. The phellogen, at the time of collection, had ceased activity, and all cells of the phellem were equally well suberized.

The pericycle, which is disrupted by the formation of a phelloderm, is composed of cells of three types: parenchyma, pericyclic fibers, and stone cells (Pl. LVII, fig. 7). The pericyclic fibers, which are situated at the extreme outer edge of the pericycle, are, upon formation of a phellogen, separated from the rest of the pericycle. On mature stems occasional fibers may still be seen clinging to the first-formed cells of the phellem. Longitudinal rows of stone cells occur at irregular intervals, usually two or three rows of cells being grouped together. Both pericyclic fibers and stone cells are highly lignified.

A narrow band of phloëm, which is somewhat crushed in places, surrounds the cylinder of xylem. The sieve tubes are quite prominent in the uncrushed areas, but sieve plates seemingly are few in number.

The secondary xylem can be distinguished from the primary

xylem by the fact that the cells of the secondary xylem are very regularly formed, which is not so true of the primary xylem; also the cells are not so large in diameter in the secondary xylem. Tracheal vessels are comparatively few in number and have an irregular distribution throughout the xylem. They are represented by spiral and scalariform types of secondary thickening in the primary xylem, and by reticulate and reticulate-pitted in the secondary xylem. The bulk of the wood is composed of wood fibers and tracheids (Pl. LVII, figs. 4 and 6), no parenchyma being present. The comparative numbers of fibers and tracheids present seem to be slightly in favor of tracheids in both primary and secondary xylem; however, the tracheids are very fiberlike in form (Pl. LVII, fig. 4), especially in the secondary xylem.

Parenchyma cells, occupying the central position in the stem, are large cells with diameters essentially equal. The cell walls are comparatively thin, but are well lignified throughout the pith.

Food products present in the stem during late summer are starch and protein. The starch, although not in any great abundance, is stored in the pith. Protein is present in the phloëm in sufficient quantities to give a good protein test.

ROOT. In the early ontogeny of the roots a phellogen is formed by cells of the pericycle just beneath the endodermis. The epidermis, cortex and endodermis are ruptured and, due to decay and mechanical strain, are soon no longer visible. The cork tissue forms a thick, smooth layer, broken only by occasional lenticels. The cell walls are rigid and well suberized.

The pericycle, remaining inside of the periderm, as seen in transverse sections, is an unbroken ring of tissue with minute intercellular spaces. Its component cells are largely parenchymatous in nature, with scattered groups of stone cells formed in longitudinal series (Pl. LVII, fig. 8). The primary cells of the pericycle retain their ability to initiate new cells, and so in the mature, fleshy root, measuring about 15 mm. in diameter, it is quite common to find the pericycle 1.4 mm. in width. The cell walls of the pericyclic parenchyma are of cellulose, while the stone cells have heavily lignified walls.

The central part of the root is composed largely of parenchyma-storage cells, among which are scattered tracheal vessels, tracheids, and wood fibers. The fibers and conducting elements are few in number, especially are there few fibers. The conducting and strengthening elements of the xylem are in small radial strands. The water-conducting elements, although few in number, are larger in diameter

than those of the stem (Pl. LVII, fig. 3), and because of the low water requirement of the shoot they are able to carry an ample supply.

Parenchyma cells of the xylem are highly functional as storage organs for starch. Starch is also stored in the pericyclic parenchyma, but in decidedly smaller amounts.

LEAF. The normal epidermal cells are probably rectangular in face view, but because of the frequent irregularities caused by epidermal hairs and stomata, there are many which differ from this type. The number of hairs on the upper surface of the leaf averages about 40 per square mm. and on the lower surface about 44. On the upper surface 45 per cent of the epidermal hairs are long, reflex-barbed hairs, 52 per cent are short hairs with reflex barbs at the apex only, and 2 per cent are long, pointed hairs, as described in connection with the stem of this plant. The proportion of hair types for the under surface of the leaf is somewhat the same, there being slightly fewer large, reflex-barbed hairs, and more long, pointed hairs.

The cell walls of the epidermal hairs and subsidiary cells, as was also true of the stem, are composed of strongly silicified cellulose. Calcium carbonate as a lining of the large types of epidermal hairs, and of the subsidiary cells in less amount, is very common. This lining many times is quite thick in the basal region of the hair, being often thicker than the cell wall, while the lumen of the narrower part, from just above the base to the apex, is entirely filled with calcium carbonate. The epidermal hairs are covered with the thin cuticle which is present on the regular epidermal cells.

About 16 stomata per square mm. are present on the upper surface of the leaf, and 23 on the lower. These stomata, with raised guard cells, are of the common type. Although this type of stoma is most common among the mesophytes, in *M. oligosperma* it is well protected by the dense covering of epidermal hairs.

The mesophyll of the leaf consists of a single layer of palisade parenchyma occupying approximately the upper half of the leaf, and a loosely joined, spongy parenchyma. A small amount of starch may be found in the palisade parenchyma, and a larger amount in the guard cells and spongy parenchyma.

Vascular bundles forming the veins are not prominent, those present having as their main conducting tissue small groups of spiral elements. The proportion of phloëm and strengthening tissue is small. The midrib, although quite outstanding, has also but little

vascular tissue (Pl. LIX, fig. 3). The strengthening tissue of the midrib, in addition to the water-conducting tissue, is composed of a small group of fibers just beneath the vascular bundle, and a few collenchyma cells at the lower and upper sides.

FRUIT. The epidermis of the capsule is very similar to that of the foliage leaf, with the exception of absence of stomata. Chloroplasts are present in the outermost parenchyma cells of the mesophyll, and a small amount of starch is found throughout the entire tissue. Near the center of the mesophyll vascular strands are present at regular intervals. These strands, about twelve to fourteen in number, are made up of conductive tissue and very thick-walled fibers. They enter the mesophyll at the base of the capsule and continue, without branching, to the summit.

At maturity the seeds have testas composed of very characteristic stone cells, which in face view appear very ordinary (Pl. LVI, fig. 11), but in cross section are quite unlike most stone cells (Pl. LVI, fig. 12). They are composed of a primary wall, a secondary wall of cellulose with which is associated hemicellulose, and a tertiary wall of cellulose. The secondary wall has every appearance of formation in both centrifugal and centripetal direction. Although developmental studies were not made of these cells, it seems justifiable to conclude that points projecting from regions of maximum thickness are formed in a centrifugal direction, while an even layer of nearly equal thickness formed in a centripetal direction is present throughout the entire cell. The tertiary wall lining the lumen of the cell is of cellulose and has thickenings in the form of longitudinal bars. The secondary wall in particular has an abundance of calcium carbonate in a noncrystalline form.

Just beneath the testa is the tegmen, consisting of a thin layer of crushed cells (Pl. LVI, fig. 8-B). These cells have cellulose walls, and in many sections are difficult to distinguish from a similar layer just beneath, which is a remnant of the nucellus. A well-developed endosperm is present, which is composed of rounded parenchyma cells. The cell walls are of cellulose, and intercellular spaces are large and numerous. This endosperm is especially rich in stored foods in the form of fatty oils and aleurone. Some seeds, when sectioned, show the presence of homogeneous masses of oil and protein around the embryo, or in breaks in the endosperm and between loosely joined cells of the endosperm (Pl. LVI, fig. 8-E). It is very likely that this material has been turned loose by the breaking down of endosperm cells.

The embryo is composed of relatively large plano-convex cotyledons, and a short, radicle-hypocotylar region. A differentiation of tissue is shown in the radicle and hypocotyl by a definite epidermis, isodiametric parenchyma cells, and by procambium strands. The cotyledons also show the presence of an epidermis, procambium strands, isodiametric parenchyma, and palisade parenchyma (Pl. LVIII, fig. 2). The palisade layer, as was also true of the foliage leaf, is one cell in width.

Reserve food is stored in all parts of the embryo. This stored food is very similar to that of the endosperm, there being large quantities of both fatty oil and aleurone present.

Mentzelia decapetala

STEM.—The epidermis of the stem of *M. decapetala* is composed of irregular cells which often have undulated radial walls, the outer wall being slightly thicker than the inner, and in face view appearing as if furrowed, as will be explained in more detail in relation to leaves, where this feature is more pronounced.

The functional duration of the epidermis is usually that of a single season, after which time a phellogen is formed by the pericyclic parenchyma just beneath the pericyclic fibers. On the oldest stems the pericyclic fibers are still visible clinging to the first-formed cells of the phellem. Also patches of cortex and epidermis still cling to the stem, but are not present in sufficient quantities to affect the appearance of the stem.

The cortex of a one-year-old stem is composed of a narrow band of large, nearly isodiametric, cells. At a slightly older stage the cell walls become undulated, a character of the cell wall very probably caused by the formation of the phelloderm and possibly one or two layers of phellem when the stem is quite young, prohibiting the passage into the cortex of water and food substances, so the cells of the cortex and epidermis gradually lose their turgidity and diminish in size to such an extent that their thin cell walls fall into folds (Pl. LIX, fig. 1).

The pericycle in the young stem is composed of thin-walled parenchyma cells and pericyclic fibers. These fibers are unusually large cells, commonly being about 3 mm. in length (Pl. LVII, fig. 15). The cell walls are only moderately thick and but slightly lignified. Compound crystals of calcium oxalate are occasionally present in the pericycle parenchyma and in the pith (see below).

The phloëm is represented by a narrow band of very small cells,

the sieve tubes measuring not more than 5 microns in diameter. Although sieve tubes and companion cells may definitely be seen, the presence of sieve plates is not apparent.

Tracheal vessels are quite numerous in both primary and secondary xylem; they are, however, very small in diameter. The primary xylem is represented by vessels with spiral, scalariform and reticulate type of secondary thickenings, while the secondary xylem has only pitted-type vessels. Tracheids and fibers are both present in great abundance in the secondary xylem. Pith-rays extend for a short distance into the primary xylem, but never extend into the secondary xylem.

The cells of the pith lack uniformity in size. The larger and the smaller cells, however, are usually grouped together (Pl. LIX, fig. 7). This grouping may not always be seen in a transverse section, because a longitudinal grouping is most common. Calcium oxalate crystals are not uncommon in the pith, but when present the compound crystals are usually small.

Reserve food in the form of glucosides is present in large quantities throughout the stems, but is present in larger quantities in the pericycle.

ROOT. Epidermal, cortical tissues and endodermis are early in the development of the root sloughed off, because of the formation of a pericyclic periderm. The phellogen takes its origin from the outer pericyclic parenchyma cells and is functional only for a short period, then its cells mature into cork cells. The cork cells on the old roots are usually badly crushed, but are highly suberized, so serve well as a protection.

The pericycle of the root increases in width until in a mature root measuring about 25 mm. in diameter the pericycle may commonly be as much as 2.5 mm. in width. The bulk of this region is made up of parenchymatous cells varying in shape. Groups of stone cells are scattered irregularly among the typical parenchyma cells, but are confined mostly to the inner half of the pericycle. These stone cells are usually in groups of two or three, as seen in transverse section, forming long radial strands. Compound crystals of calcium oxalate are very abundant in the pericycle. Usually they are situated in small parenchyma cells measuring about .024 mm. in diameter.

In structure the phloëm in the root corresponds very closely with that of the stem, with possible exception of being even reduced more

in extent. Sufficient protein is present in scattered groups of cells in the phloëm to give a protein test.

Tracheal vessels are quite numerous in both primary and secondary xylem. Conducting elements in the primary and secondary xylem are represented by vessels with scalariform and reticulate secondary thickenings as the dominant cell type. Few tracheids and fiber tracheids are present in the primary xylem and only occasional spiral element, but both tracheids and wood fibers are quite abundant in the secondary xylem. Xylem rays, usually about four cells in width in the secondary xylem and much wider in the primary xylem, extend from near the center of the root to the pericycle. Compound crystals of calcium oxalate are present in scattered cells of the xylem rays, but are by far less abundant than in the pericycle.

The reserve food, which is in the form of glucosides, is present in the stele of the root, but the amount present is smaller than that of the stem.

LEAF. The epidermis of the leaf is composed of comparatively small cells with thick cell walls. The regular epidermal cells and subsidiary cells of the hairs are covered with a cuticle which is formed in ridges which may be continuous from one cell to another. These ridges are most commonly from two to three microns in height, but it is not uncommon for them to be as high as four or five microns. Their composition is purely that of cutin, which may be completely removed by boiling in a 3 per cent alcoholic solution of potassium hydroxide.

Heavy silicified epidermal hairs are quite abundant on both upper and lower leaf surfaces, there being about eight hairs per square mm. of leaf surface. About 75 per cent of the hairs present are conical in shape, with blunt barbs (Pl. LVI, fig. 4), and 25 per cent are short hairs with reflexed barbs at the apex (Pl. LVI, fig. 3). The inner wall of the conical hairs and of the subsidiary cells are roughened and are made to seem more irregular by the presence of small patches of calcium oxalate.

The mesophyll of the leaf is composed largely of palisade parenchyma. A single layer of these cells is present beneath both upper and lower epidermal surfaces, leaving only a relatively small area through the center of the leaf for spongy parenchyma and vascular tissue. Frequently the cell walls of palisade parenchyma in contact with the enlarged base of an epidermal hair become silicified. When this is reduced to ash a skeleton of silica remains, appearing as a

meshwork below the bulbous base of the epidermal hair (Pl. LVIII, fig. 4).

The midrib, although not prominent, contains considerable conductive tissue. At the base of the leaf, and proceeding into the leaf for often 8 mm., are three separate vascular bundles, which then merge to form a single bundle. The strengthening tissue consists of xylem, and collenchyma at both upper and lower surfaces of the midrib near the base of the leaf, but it is not formed near the tip.

FRUIT. The epidermis of the capsule is very similar to that of the stem, with exception of there being hardly so many epidermal hairs per surface area. The mesophyll is composed largely of irregular parenchyma cells with large intercellular air spaces. Compound crystals of calcium oxalate are very abundant in this tissue, but are localized largely in the innermost cells, and in particular around the seeds. Mechanical strength is furnished by thick-walled fibers associated with numerous radially arranged vascular strands. The strands are frequently connected by branching vascular elements, fibers and thick-walled parenchyma.

The testa and wing of the seed are composed of characteristic stone cells with thick cellulose walls (Pl. LVI, fig. 13). These cells are quite irregular in outline as is also the case of their homologues in *M. oligosperma.* The tegmen is composed of a single layer of crushed cells which are difficult to distinguish from a similar layered remnant of the nucellus. Endosperm is present as a comparatively thick tissue surrounding the embryo. It is especially rich in stored protein and fatty oils. In the mature seed empty cells of the endosperm adjoining the embryo are quite common, the food from these cells having undoubtedly been used in the formation of the embryo.

The embryo is straight and has a prominent radical-hypocotylar region. The component tissues of the embryo are the epidermal, the parenchymatous cells and the procambium strands. The mesophyll of the cotyledons is composed entirely of small, nearly isodiametric, cells, there being no differentiation into palisade and spongy parenchyma. The amount and types of food stored in the embryo are practically the same as of the endosperm.

The presence of glucosides in the mesocarp of the fruit is common, but is hardly as prominent as in the root, stem, and leaves.

SUMMARY

Principal anatomical similarities and differences between *Mentzelia oligosperma* and *M. decapetala:*

POINTS OF SIMILARITY

1. Formation of phellogen by the pericycle in root and stem.
2. Component cell types of the pericycle in root and stem.
3. Growth of pericycle by cell multiplication in roots.
4. Presence of silicified subsidiary cells and epidermal hairs.
5. Kinds of food stored in embryo and endosperm—fatty oils and proteins.
6. Relatively large amounts of wood fibers in the xylem.
7. A low water requirement is indicated in the stems of *M. oligosperma* by the relatively small number of water-conducting elements, and in *M. decapetala* by only a slightly larger number of water-conducting elements which are smaller in diameter than those of *M. oligosperma.*

POINTS OF DIFFERENCE

1. Food stored in stem, root, and leaf—starch in *M. oligosperma* and glucosides in *M. decapetala.*
2. Differentiation of cell types in cotyledons—palisade cells present in *M. oligosperma* and absent in *M. decapetala.*
3. Type of stone cell making up the testa.
4. Size of component cells throughout the plant—smaller in *M. oligosperma* than in *M. decapetala.*
5. Epidermis and cuticle—undulate radial walls and ridged cuticle in *M. decapetala* without counterpart in *M. oligosperma.*
6. Presence of calcium oxalate in stone cells and epidermal hairs of *M. oligosperma,* and calcium carbonate in epidermal hairs and as compound crystals widely distributed throughout the parenchymatous tissues of *M. decapetala.*
7. Epidermal and cortical tissues of the stem of *M. decapetala* are partly sloughed off, only patches remaining attached to the cork. The epidermis and cortex of *M. oligosperma* remains more or less intact as a loose sheath around the stem.
8. Stems of *M. decapetala,* because of their having a longer growth period, reach a larger diameter than do the annual stems of *M. oligosperma.*

There are many anatomical differences between the two species

investigated, but points of similarity are sufficiently striking to indicate a close relationship.

The writer wishes to acknowledge the assistance received from Prof. W. C. Stevens, who suggested this problem, supplied material, and offered many valuable suggestions throughout the course of investigation and in preparation of the manuscript.

CELL MEASUREMENTS FROM TISSUES REPRESENTED IN STEM AND ROOT

Cell type from stem.	*Mentzelia oligosperma*, diameter in microns.				*Mentzelia decapetala*, diameter in microns.			
	Long.	Tang.	Radial.	Wall.	Long.	Tang.	Radial.	Wall.
Epidermis	22	20	44	3.2	....	30	23	3, 2.8
Parenchyma of cortex	52	23	15	2.0	100	28	10	1.3
Pericyclic fiber	920	48	24	5.0	3,100	18	20	8.0
Pericyclic parenchyma	52	46	32	2.2	30	20	36	3.0
Pericyclic stone cell	131	43	39	12.4	....	....	....	....
Sieve tubes	....	12	8	.8	....	8	8	.8
Companion cell	....	6 ±	6 ±	.8	....	5 ±	5 ±	.8
Vessel segment	320	41	58	5.2	....	20	32	2.2
Tracheid	580	24	28	5.0	590	14	16	2.0
Wood fibre	614	20	20	6.0	630	10	16	2.0
Parenchyma of pith	120	100	100	3.0	60	52–30	80	1.3
Phellem	240	40	18	3.2	78	52	22	....
Cell type from root.								
Phellem	96	60	24	3.0	102	60	15	2.0
Pericyclic parenchyma	100	100–4	40–32	2.5	140	140–30	52–32	1.3
Pericyclic stone cells	71	25	25	9.2	120	40	36	10.0
Sieve tubes	....	12	12	1.0	....	8	8	.8
Companion cells	....	7—	7—	1.0	....	6 ±	6 ±	.8
Parenchyma of xylem	78	76	36	2.0	40 ±	12 ±	10 ±	1.3
Tracheal vessel	240	160	144	6.0	40	53	58	6.0
Tracheid	300	20	20	4.0	600	32	30	3.5
Wood fibre	381	20	20	4.5	654	23	23	3.4

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PLATE LVI

FIG. 1. Reflex-barbed epidermal hair from the leaf of *M. oligosperma*. $\times$ 73.3.

FIG. 2. Long-pointed epidermal hair from the leaf of *M. oligosperma*. $\times$ 73.3.

FIG. 3. Short epidermal hair which is present on either *M. oligosperma* or *M. decapetala*. $\times$ 73.3.

FIG. 4. Short-pointed epidermal hair from leaf of *M. decapetala*. $\times$ 73.3.

FIG. 5. Face view of the subsidiary cells of an epidermal hair from the leaf of *M. oligosperma*. $\times$ 73.3.

FIG. 6. Face view of the subsidiary cells of an epidermal hair from the leaf of *M. decapetala*. $\times$ 73.3.

FIG. 7. Outline drawing from a transverse section of a seed of *M. decapetala*. $\times$ 40. A, testa; B, tegmen; C, perisperm; E, oily-proteinaceous material from the endosperm; f, cotyledon.

FIG. 8. Outline drawing from a transverse section of a seed of *M. oligosperma*. $\times$ 40. A, testa; B, tegman; C, perisperm; E, endosperm; F, cotyledon.

FIG. 9. Outline drawing from face view of cells composing the outer seed coat of *M. oligosperma*. $\times$ 75.

FIG. 10. Outline drawing from face view of cells composing the outer seed coat of *M. decapetala*. $\times$ 75.

FIG. 11. Transverse section of stone cells from testa of *M. oligosperma*. $\times$ 150.

FIG. 12. Face view of a stone cell from the testa of *M. oligosperma*. $\times$ 150.

FIG. 13. Transverse section of stone cells from testa of *M. decapetala*. $\times$ 150.

FIG. 14. Seed of *M. decapetala*. $\times$ 3.3.

FIG. 15. Seed of *M. oligosperma*. $\times$ 3.3.

PLATE LVI

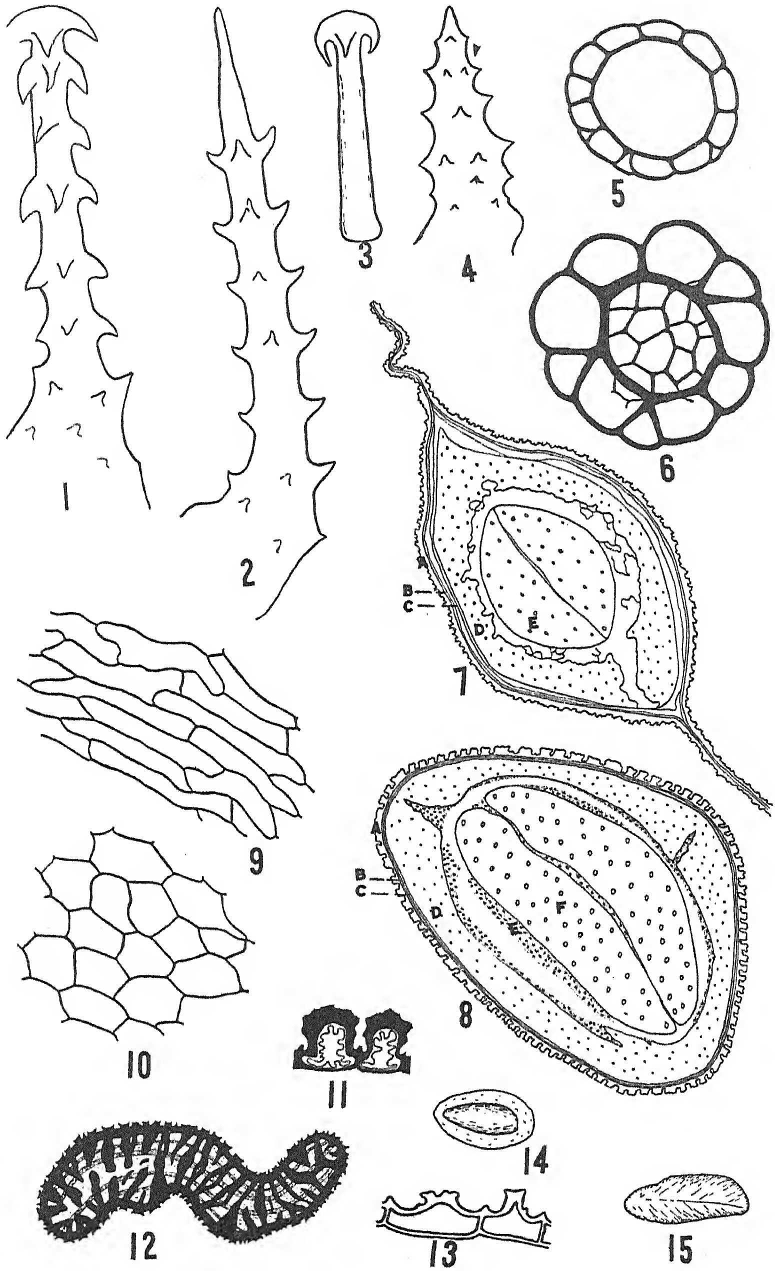


PLATE LVII

FIG. 1. Part of tracheal elements from primary xylem of stem of *M. oligosperma*. × 183.

FIG. 2. Vessel segment from stem of *M. oligosperma*. × 183.

FIG. 3. Vessel segment from root of *M. oligosperma*. × 183.

FIG. 4. Tracheid from stem of *M. oligosperma*. × 183.

FIG. 5. Wood fiber from root of *M. oligosperma*. × 183.

FIG. 6. Wood fiber from stem of *M. oligosperma*. × 183.

FIG. 7. Stone cell from stem of *M. oligosperma*. × 183.

FIG. 8. Stone cell from root of *M. oligosperma*. × 183.

FIG. 9. Part of tracheal elements from primary xylem of stem of *M. decapetala*. × 183.

FIG. 10. Vessel segment from stem of *M. decapetala*. × 183.

FIG. 11. Wood fiber from root of *M. decapetala*. × 183.

FIG. 12. Wood fiber from stem of *M. decapetala*. × 183.

FIG. 13. Tracheid from stem of *M. decapetala*. × 183.

FIG. 14. Part of a pericyclic fiber from stem of *M. decapetala*. × 183.

FIG. 15. Pericycle fiber from stem of *M. decapetala*. Half of cell is shown. × 40.

FIG. 16. Vessel segment from root of *M. decapetala*. × 183.

FIG. 17. Stone cell from pericycle of root of *M. decapetala*. × 183.

PLATE LVII

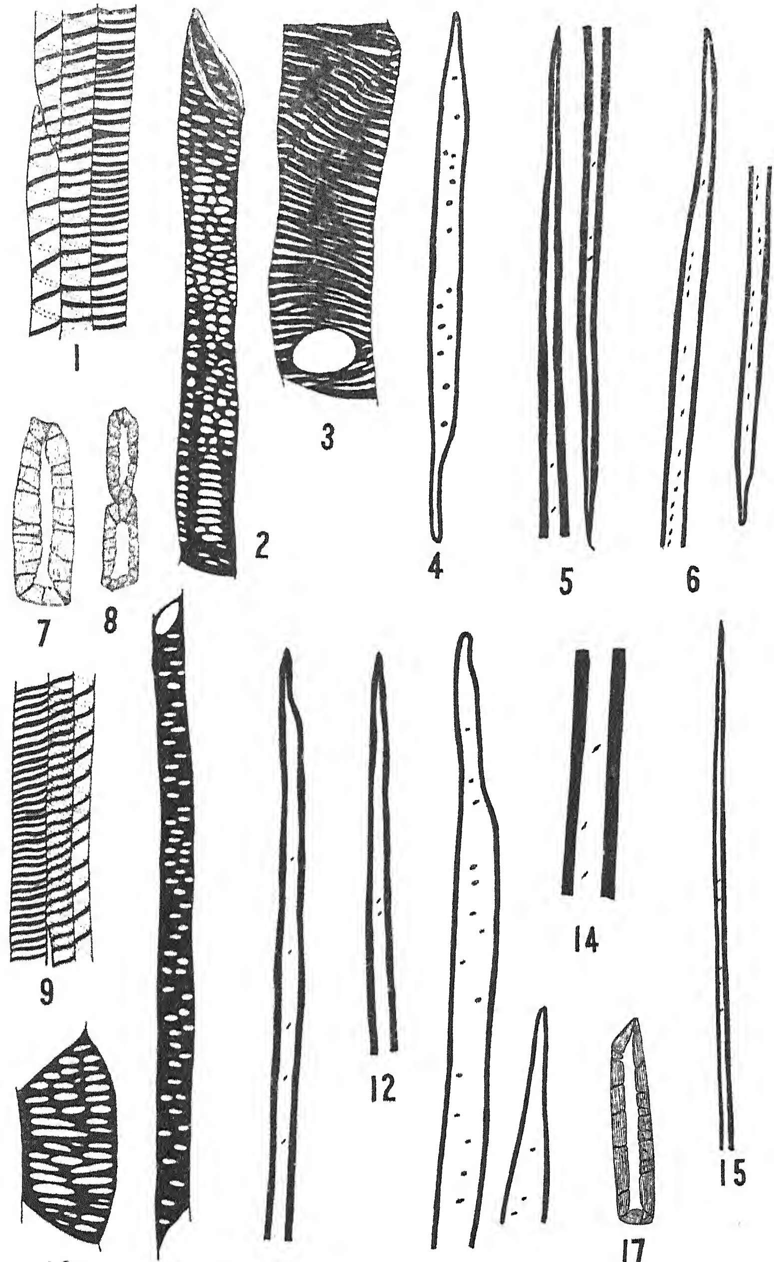


PLATE LVIII

FIG. 1. A part of a young shoot of *M. oligosperma.*

FIG. 2. Longitudinal section from the seed of *M. oligosperma.* $\times$ 37.5.

FIG. 3. *M. oligosperma* showing a part of the fleshy root system and the shaggy characteristic of the stems. $\times$ 37.5.

FIG. 4. Silicified subsidiary cells of *M. decapetala.*

FIG. 5. Transverse section from the seed of *M. decapetala.* $\times$ 37.5.

FIG. 6. Leaf margin of *M. decapetala.* $\times$ 65.

FIG. 7. Longitudinal section from the seed of *M. decapetala* showing but little differentiation of tissue. $\times$ 37.5.

FIG. 8. Ash from *M. oligosperma* showing the silicified basal cells of an epidermal hair.

FIG. 9. Transverse section from the seed of *M. oligosperma* through hypocotylar region. $\times$ 37.5.

FIG. 10. *M. decapetala* in native habitat.

FIG. 11. Leaf margin of *M. oligosperma.* $\times$ 65.

PLATE LVIII

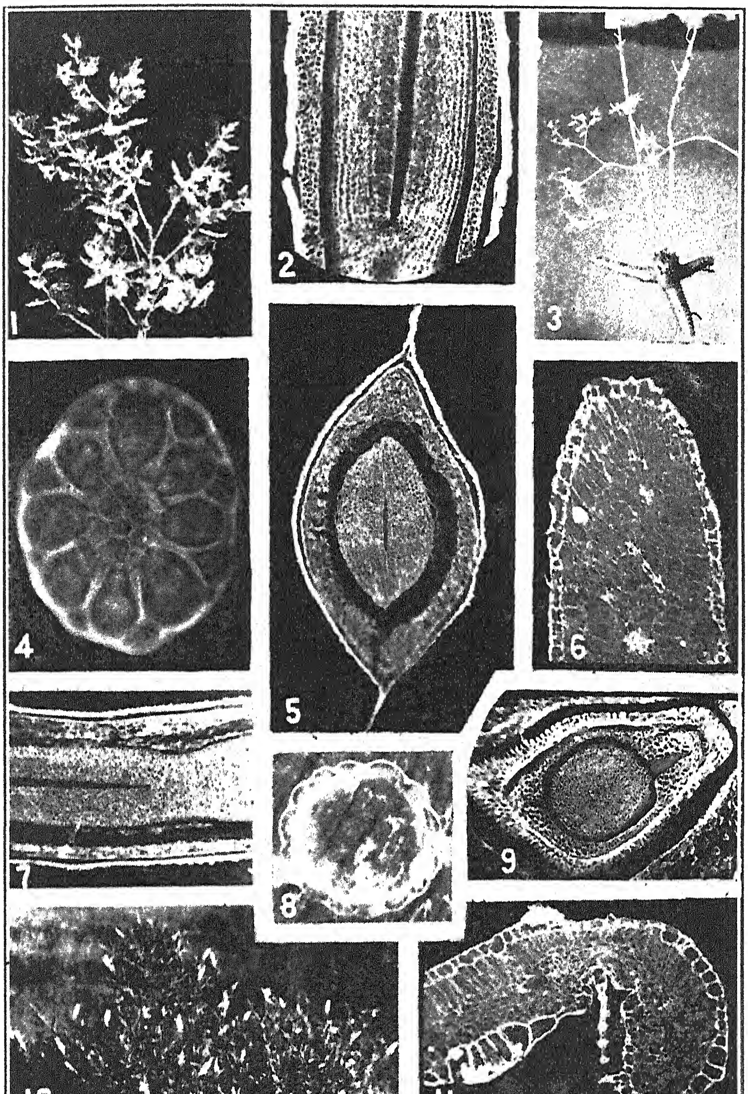


PLATE LIX

FIG. 1. Sector from transverse section of stem of *M. decapetala*. $\times$ 65.

FIG. 2. Sector from transverse section of stem of *M. oligosperma*. $\times$ 65.

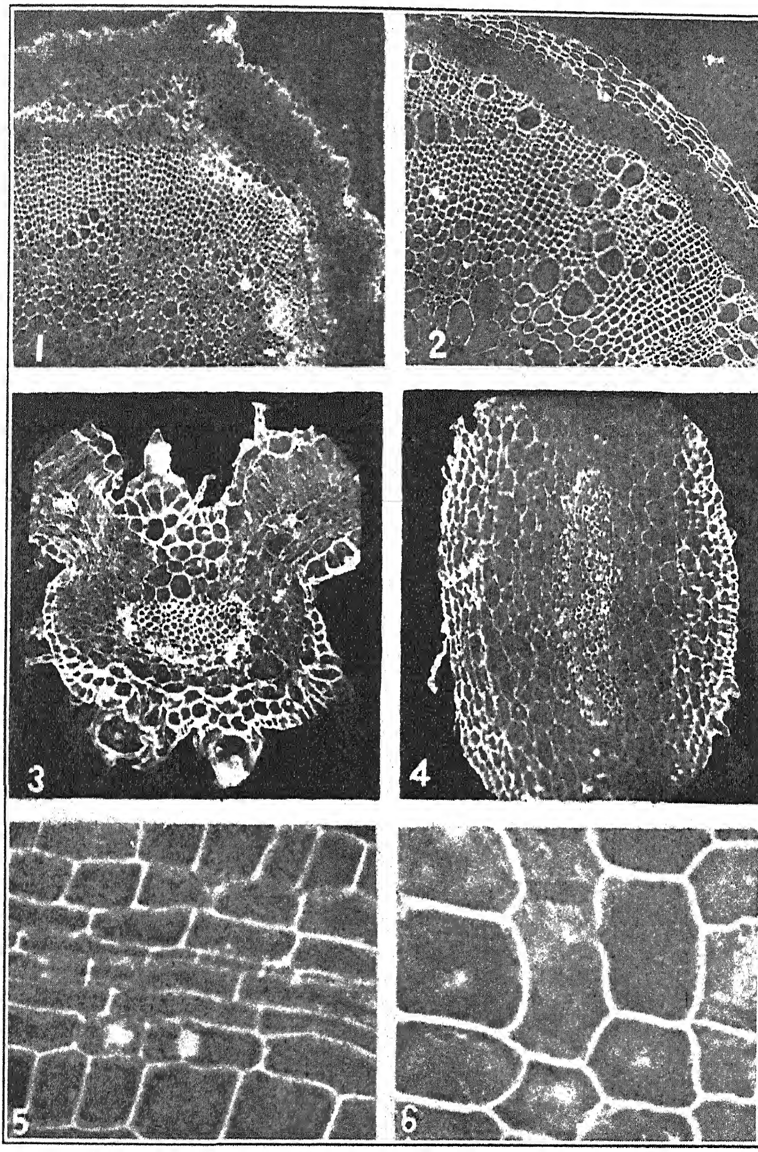
FIG. 3. Transverse section of midrib of *M. decapetala*. $\times$ 65.

FIG. 4. Transverse section of midrib of *M. oligosperma*. $\times$ 65.

FIG. 5. Longitudinal section of pith cells from the stem of *M. decapetala* showing the irregularity in size and shape of the cells. $\times$ 200.

FIG. 6. Longitudinal section of pith cells from the stem of *M. oligosperma* showing that there is not a great irregularity in shape of the component cells. $\times$ 200.

PLATE LIX



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Some Studies on the Transference of Ions in Anhydrous Acetic Acid Solution

ARTHUR W. DAVIDSON and VERNON HOLM,[1]
Department of Chemistry, University of Kansas

ABSTRACT: Transference measurements were made by the Hittorf analytical method on sodium and ammonium acetates in acetic acid solution, as well as on sodium zinc acetate and on ammonium cupric acetate solutions. In the case of the alkali acetates the apparent transport numbers of the cations were found to be surprisingly small, and to decrease with increasing dilution, becoming practically zero in the most dilute solutions studied (about 1 mole per cent, or 0.15 molal). It is suggested that these anomalous values may be due to the presence of complex ions. In the case of the double acetate solutions it had been expected that the less positive metal might be found to migrate toward the anode, but no such result was obtained.

INTRODUCTION

AMPHOTERISM IN WATER, AMMONIA AND ACETIC ACID SOLUTIONS

It is a familiar fact that zinc hydroxide dissolves in aqueous solutions of sodium hydroxide, and that at very high concentrations of alkali a compound called sodium zincate may be isolated from such solutions. The formula for this compound which appears to be best substantiated is that given by Goudriaan,[2] $Na_2ZnO_2 \cdot 4H_2O$. It is obvious that this compound might equally well be formulated as $Zn(OH)_2 \cdot 2NaOH \cdot 2H_2O$, and might be regarded as an addition compound of the two hydroxides. Analogous compounds are formed when strongly alkaline solutions react with any

1. This paper was constructed from a thesis submitted by Vernon Holm in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Kansas, June, 1932.

2. Goudriaan, Rec. trav. chim., 39, 505 (1920).

of the so-called amphoteric hydroxides, such as those of aluminum, lead and tin. Further, this type of reaction is not peculiar to aqueous solutions. It has been shown, mainly by Franklin and his coworkers,[3] to be of even more common occurrence in liquid ammonia; a large number of amides (bases of the ammonia system) react with potassium amide to form addition compounds. Further evidence of the general nature of this phenomenon has been found from the study of solutions in acetic acid. In a recent paper from this laboratory[4] it was shown that some of the properties of solutions of zinc and sodium acetates in acetic acid are closely parallel to those of the corresponding aqueous system; the solubility of zinc acetate increases with increasing concentration of sodium acetate until the compound $Zn(C_2H_3O_2)_2 \cdot 2NaC_2H_3O_2 \cdot 4HC_2H_3O_2$ appears as solid phase. Similarly, cupric acetate dissolves in potassium or ammonium acetate solutions, and in the latter case a compound of the formula $Cu(C_2H_3O_2)_2 \cdot 4NH_4C_2H_3O_2 \cdot 4HC_2H_3O_2$ has been isolated.[5] If an amphoteric base be regarded as one which is capable of combining with stronger bases to give addition compounds, all of the cases cited may obviously be regarded as instances of amphoterism.

In the case of aqueous solutions, compounds of the type under consideration are commonly regarded as salts, and are assumed to dissociate so as to yield anions containing the less positive metal. The name "metallate" has been suggested[6] as a general term for all such salts. In general, the evidence for this sort of dissociation is far from conclusive. However, in the case of sodium zincate, at least, it has been shown that during electrolysis the concentration of zinc increases in the neighborhood of the anode,[7] which is in accord with the hypothesis that the zincate ion, $HZnO_2^-$, is present in such solutions. In the ammonia system the existence of metallate ions was merely taken for granted until very recently, when Detrick and Fernelius, in an unpublished paper,[8] reported that, in the electrolysis of liquid ammonia solutions of potassium ammonoaluminate, $Al(NH_2)_3 \cdot KNH_2 \cdot NH_3$ or $Al(NH_2)_2NHK \cdot 2NH_3$, potassium ammonoplumbite, $PbNH \cdot KNH_2$ or $PbNK \cdot NH_3$, and potassium ammonocuprite, $CuNH_2 \cdot 2KNH_2 \cdot NH_3$ or $CuNK_2 \cdot 3NH_3$, the less

3. For a summary see Bergstrom and Fernelius, Chem. Reviews, 12, 51 (1933).
4. Davidson and McAllister, J. Am. Chem. Soc., 52, 519 (1930).
5. Davidson and Griswold, ibid., 53, 1341 (1931).
6. Fernelius and Bergstrom, J. Phys. Chem., 35, 741 (1931).
7. Kremann, Z. anorg. Chem., 33, 87 (1902).
8. Presented at the Indianapolis meeting of the American Chemical Society, April, 1931.

positive metal was almost quantitatively deposited on the anode, in every case, in the form of a nitrogen compound. The authors regard this as evidence that these compounds are true metallates and not merely double amides.

Because of the marked analogy between the sodium zinc acetate and the ammonium cupric acetate mentioned above, and corresponding compounds in the water and ammonia systems, the question naturally arises whether or not the former compounds are true metallates; or, in other words, whether the amphoterism of zinc and cupric acetates in acetic acid includes the property of forming metallate ions in the presence of excess of acetate ion, or whether it is limited to their tendency to form addition compounds with stronger bases. It was in the attempt to throw additional light on this question that the present work was undertaken.

METHOD

GENERAL PLAN. It was hoped that some indication of the ionic species present in such acetic acid solutions as have just been discussed might be obtained by means of a study of their behavior during electrolysis. The method chosen was that first used by Hittorf [9] in the determination of transference numbers—that is, the measurement of the changes in concentration, during electrolysis, of the solution surrounding one or both of the electrodes. It was originally planned to employ this method merely to determine the *direction* of migration of the less positive metal, but the results of preliminary experiments indicated such marked anomalies of transference that it appeared desirable first to determine quantitatively the migration ratios in some simpler systems, especially since no such experiments on acetic acid solutions have hitherto been reported.[10]

PRELIMINARY EXPERIMENTS. In the earliest experiments it was found that, due to the high resistance of the acetic acid solutions to be studied, an electromotive force of 110 volts was insufficient to bring about appreciable concentration changes in a reasonable period of time. Hence a transformer and rectifier capable of giving 600 volts were used in the subsequent work. This device, as well

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9. (a) Hittorf, "Ueber die Wanderungen der Ionen während der Elektrolyse," Ostwald's Klassiker der exacten Wissenschaften, vol. 21, 23, Leipzig, 1903-4. See, also, (b) Drucker, "Ostwald-Luther Hand und Hilfsbuch zur Ausführung physiko-chemischer Messungen," Leipzig, 1931, pp. 688-96.

10. Transference numbers in acetic acid solutions have, however, been determined by the moving boundary method by Longsworth (Thesis, University of Kansas, 1928), who concluded that the transference numbers of sodium and potassium acetates changed little with concentration, and approached a value of 0.5 in dilute solutions.

as the cell used for the quantitative experiments, will be described later.

When a solution of sodium and zinc acetates was electrolyzed, at a low current density, between platinum electrodes, hydrogen was evolved at the cathode, but no gas bubbles whatever could be observed at the anode. It appeared, therefore, that it would be preferable to study concentration changes around the anode, where there would be no disturbance due to evolution of gas, and some preliminary trials were made with this end in view. In one case a white deposit, shown by analysis to be zinc acetate, was obtained on the anode. This result, which suggested the presence of an anion containing zinc, could not be duplicated, however. Further experience showed that it would be difficult to determine the exact nature of the anode reaction occurring in these solutions, or, for that matter, even in solutions of alkali acetates electrolyzed under these conditions.[11] It was accordingly decided to set up a cell with a reversible and definitely known anode reaction. After some unsuccessful experiments with zinc amalgam, a mercury anode was tried and proved to be satisfactory. On passage of the current, a white deposit appeared above the mercury; the decrease in weight of the metal agreed with that calculated, on the basis of oxidation to the mercurous state, from the quantity of electricity. The deposit was found to yield mercurous ion, but no mercuric, and must therefore have been mercurous acetate; this compound was so insoluble that no perceptible precipitate with hydrogen sulfide was obtained, in any case, in the supernatant solution. No evolution of gas was detectable with this electrode at current densities up to 0.8 ampere per square decimeter.

APPARATUS. The cell[12] used in the quantitative experiments was of the Loeb-Nernst type,[13] and is pictured in figure 1. Mercury in the bottom of the longer leg served as anode, connection to which was made by means of a platinum wire sealed through a glass tube. This tube, filled with mercury, was held in place by a rubber stopper, which carried also a tube filled with calcium chloride, in order that moisture might be excluded. The cathode was a piece of platinum foil, to which connection was made by means of a long platinum wire of fine gauge. In order to minimize the stirring effect of gas

11. Hopfgartner (Monatsh., 32, 523 [1911]) studied the electrolysis of sodium acetate between platinum electrodes and found that carbon dioxide, ethane, oxygen, methyl acetate and other substances were formed at the anode, the relative quantities varying with current density, concentration and temperature.

12. The writers are indebted to Mr. Jesse Stareck for the construction of this cell.

13. Ref. 9b, p. 689.

liberated at the cathode, a funnel-shaped deflector was placed with its wider end over the cathode, while the smaller end passed through the stopper of the cathode compartment and was connected to a second drying tube. A small hole in the deflector tube above the

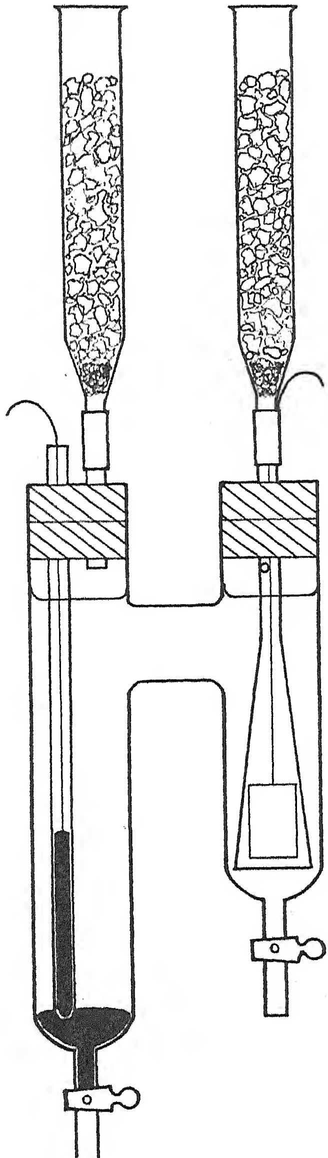

FIG. 1. Cell used for transference measurements.

surface of the liquid allowed atmospheric pressure to be maintained in this part of the cell. The cathode lead wire passed out through the end of the deflector and under the rubber tubing which made connection with the drying tube, as shown in the diagram.

The source of current was a Majestic B battery eliminator which had been rebuilt to deliver a maximum of about 600 volts when connected in the 110-volt alternating-current circuit; a Kenetron tube (type 280) served as rectifier, and a rheostat, connected across the alternating-current input, made it possible to adjust the voltage. The secondary (direct-current) circuit contained the electrolytic cell described above, a standard copper coulometer and a Weston three-range ammeter.

PREPARATION OF MATERIALS. The anhydrous acetic acid was prepared by the method of Kendall and Gross;[14] the product used in this work had a freezing point of 16.5-6°. The sodium acetate was dehydrated for several days at 150° and then kept in stoppered bottles in a desiccator. Its purity was verified by checking the freezing points of several solutions of the salt in acetic acid against the data of Kendall and Adler.[15] Anhydrous zinc acetate was prepared as described in a previous paper from this laboratory;[4] analysis for zinc by potentiometric titration with potassium ferrocyanide solution gave 35.70 per cent, as compared with the calculated 35.65 per cent. Ammonium acetate was obtained by passing anhydrous ammonia over acetic acid, as described in the same paper; it was found that either the normal salt $NH_4C_2H_3O_2$ or the solvate $NH_4C_2H_3O_2 \cdot HC_2H_3O_2$ might be obtained by this method, but since the concentration of all ammonium acetate solutions was determined by analysis, the relative amounts of the components ammonia and acetic acid in the salt used for preparing them was of no consequence, as long as no other substances were present. Cupric acetate was prepared as described in another paper already referred to;[5] analysis for copper by the electrolytic method gave 34.96 per cent, as compared with the calculated 35 per cent.

ANALYSIS OF THE SOLUTIONS. Solutions of sodium acetate were analyzed by adding a slight excess of sulfuric acid, evaporating slowly to dryness, heating gently until the excess sulfuric acid had been driven off and then strongly to constant weight of sodium sulfate. In the case of solutions containing both sodium and zinc, the zinc was determined by potentiometric titration with potassium ferrocyanide solution. Attempts to determine both metals in the

14. Kendall and Gross, J. Am. Chem. Soc., 43, 1426 (1921).
15. Kendall and Adler, ibid., 43, 1470 (1921).

same sample failed to yield results as consistent as desired, and since a high degree of accuracy in the analyses was essential if the transport figures were to have any significance, this plan was not followed. The analyses for cupric acetate were made by the iodimetric method, and those for ammonium acetate by adding an excess of sodium hydroxide solution and distilling the liberated ammonia into standard hydrochloric acid. In almost every case duplicate analyses were made, which agreed to well within the probable error of the Hittorf method.

MEASUREMENT OF TRANSFERENCE. Transference studies were made on acetic acid solutions of sodium and ammonium acetates over as wide a range of concentrations as possible, namely from about 1 to 7 mole per cent of solute (0.15 to 1.25 molal). More dilute solutions could not be used because of their extremely low conductivity, while at high concentrations the relative change during electrolysis would be so small as to impair the accuracy of the results. A study was made also of the transference of zinc ion in solutions containing both sodium and zinc acetates, and of cupric and ammonium ions in solutions of both of these acetates. (In these cases deposits of zinc and of copper, respectively, appeared on the cathodes during electrolysis, while no trace of zinc or of cupric acetate could be detected in the anode deposit.)

The procedure in making a run was as follows. About thirty grams of redistilled mercury were accurately weighed, and transferred to the longer leg of the electrolytic cell, which was to serve as the anode compartment. The solution to be electrolyzed was then introduced, reaching a level slightly above that of the connecting tube. The stoppers, fitted as described above, were put in place and the electrical circuit was completed. The current was adjusted to the desired value of a few milliamperes and electrolysis continued until 0.05 to 0.15 gram of copper had been deposited on the cathode of the coulometer; the time required for this varied from six to twenty-four hours. At the end of the electrolysis this cathode was immediately washed, dried and weighed. The stopcock in the cathode leg was opened and the solution from this compartment and the connecting tube slowly withdrawn. Then the total remaining contents of the anode leg were transferred to a weighed stoppered flask. After it had been weighed again, this was set aside to allow the mercurous acetate to settle out completely. Portions of the solution were then decanted into weighing bottles for analysis.

As has been stated previously, at the beginning of this work it was

not intended to determine more than the direction of transference of the metallic constituents; the data obtained, however, made it possible to calculate the apparent transport numbers of the cations in the pure sodium and ammonium acetate solutions, and the fraction of the current apparently carried by the less positive metal in the mixed acetates, although the highest degree of accuracy in these numerical values was not striven for. The temperature was that of the laboratory, about 25°C. No thermostat was used, nor was the middle portion analyzed to insure constancy of concentration in this region. It is believed, however, that the anode portion taken for analysis (usually about 30 grams, or about two-fifths of the whole solution) included all the changes caused by transference and electrode reactions at the anode. The changes in density were very slight. The transport numbers given are probably correct to ±0.05. It should be mentioned further that no attempt was made to correct the apparent transport numbers for possible solvation of the ions, as this would have involved a tremendous increase in experimental difficulties without commensurate increase in the significance of the values obtained.

RESULTS

Space does not permit the tabulation of all the data obtained. The results are summarized in the following tables.

TABLE 1.—Transference data for sodium acetate

Concentration of original solution.			Trial number.	Concentration of anode solution after electrolysis, weight per cent.	Copper deposited in coulometer, grams.	Transference of sodium acetate from anode, grams.	Apparent transport number of cation.
Mole per cent.	Molality.	Weight per cent.					
0.99	0.167	1.34	1	1.36	0.0263	—0.004	—0.08
			2	1.35	0.0580	—0.003	—0.02
			3	1.34	0.0170	0	0
			4	1.34	0.0176	0	0
			Mean	....	....	....	—0.03
2.76	0.473	3.74	5	3.69	0.0592	0.017	0.11
5.06	0.888	6.80	6	6.62	0.1279	0.066	0.20
			7	6.68	0.0716	0.048	0.26
			Mean	....	....	....	0.23
7.02	1.257	9.35	8	9.25	0.0755	0.040	0.21

TABLE 2.—Transference data for ammonium acetate

Concentration of original solution.			Trial number.	Concentration of anode solution after electrolysis, weight per cent.	Copper deposited in coulometer, grams.	Transference of ammonium acetate from anode, grams.	Apparent transport number of cation.
Mole per cent.	Molality.	Weight per cent.					
0.84	0.140	1.07	1	1.06	0.0789	0.002	0.01
			2	1.04	0.1058	0.010	0.04
			Mean	....	....	....	0.03
1.84	0.312	2.35	3	2.28	0.1533	0.025	0.07
			4	2.33	0.1076	0.008	0.03
			Mean	....	....	....	0.05
3.23	0.556	4.10	5	4.00	0.0701	0.032	0.19
			6	4.02	0.0844	0.027	0.13
			Mean	....	....	....	0.16
6.97	1.248	8.78	7	8.68	0.0752	0.035	0.19
			8	8.62	0.1175	0.061	0.21
			Mean	....	....	....	0.20

TABLE 3.—Transference data for sodium acetate-zinc acetate

Concentration of original solution.				Mole ratio zinc acetate: total solute.	Copper deposited in coulometer, grams.	Transference of zinc acetate from anode, grams.	Fraction of current carried by zinc.
Sodium acetate.		Zinc acetate.					
Mole per cent.	Molality.	Mole per cent.	Molality.				
3.35	0.579	0.27	0.047	0.074	0.0797	0.046	0.20
6.66	1.192	0.26	0.047	0.038	0.0997	0.034	0.12

TABLE 4.—Transference data for ammonium acetate-cupric acetate

Concentration of original solution.				Mole ratio cupric acetate: total solute.	Trial No.	Copper deposited in coulometer, grams.	Transference from anode, grams.		Fraction of current carried by cation.	
Ammonium acetate.		Cupric acetate.								
Mole per cent.	Molality.	Mole per cent.	Molality.				$NH_4C_2H_3O_2$	$Cu(C_2H_3O_2)_2$	NH_4^+	Cu^{++}
0.81	0.136	0.214	0.036	0.209	1	0.1342	0.015	0.089	0.04	0.23
					2	0.1119	0.011	0.083	0.04	0.26
					3	0.1379	....	0.088	....	0.22
					Mean				0.04	0.23
2.68	0.460	0.300	0.052	0.101	4	0.1438	0.015	0.099	0.04	0.24
					5	0.2339	0.028	0.116	0.05	0.17
					6	0.1345	0.020	0.077	0.06	0.20
					Mean				0.05	0.20
8.50	1.555	0.440	0.081	0.049	7	0.1818	0.060	0.073	0.14	0.14
					8	0.2112	....	0.072	....	0.12
					9	0.0693	0.020	....	0.12	....
					Mean				0.13	0.13
10.83	2.030	0.292	0.055	0.026	10	0.0976	0.088	0.024	0.37	0.08
					11	0.0956	0.100	0.022	0.43	0.08
					Mean				0.40	0.08
22.30	4.802	0.346	0.075	0.015	12	0.1203	....	0.006	....	0.02
					13	0.1194	....	0.013	....	0.04
					Mean					0.03

DISCUSSION

SODIUM ACETATE AND AMMONIUM ACETATE SOLUTIONS

The variation of the transport number of the cation in these solutions with concentration is shown graphically in figures 2 and 3. The rapid increase of the apparent transport number, and its approach to a normal value, with increasing concentration, is quite different from the behavior of most salts in aqueous solution, where migration ratios do not vary greatly with concentration. The fact that in the most dilute solution of sodium acetate the transport number apparently has a slightly negative value is particularly anomalous.

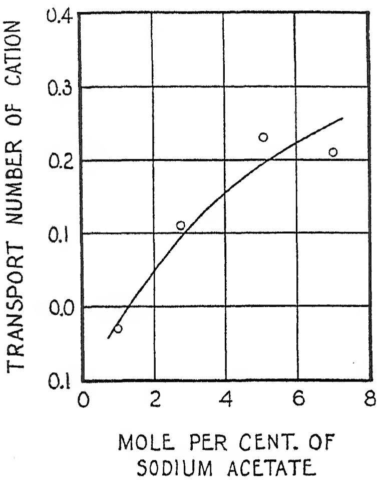

FIG. 2. Apparent transport number of cation in sodium acetate solutions.

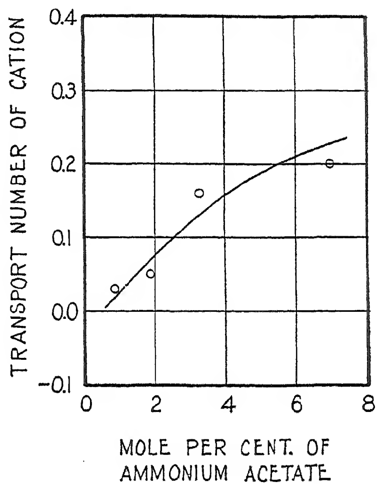

FIG. 3. Apparent transport number of cation in ammonium acetate solutions.

In the case of aqueous solutions marked abnormalities of this sort are ordinarily attributed to the formation of complex ions, as, for instance, in the case of cadmium iodide, where ions such as CdI_3^- or CdI_4^{--} are assumed to be present. It is possible that similar phenomena may occur in acetic acid solutions. Thus, in the case of sodium acetate, if we were to suppose that the dissociation followed the course shown by the equation—

$$2NaC_2H_3O_2 \rightleftharpoons Na^+ + Na(C_2H_3O_2)_2^-$$

and, further, that the two ions here shown had nearly the same mobilities, we could thereby account for the fact that there appears to be no migration of sodium from the anode in dilute solutions. It would be difficult, however, to explain why such an abnormality should be greater in dilute than in concentrated solutions.

If some knowledge of the molecular species present in an acetic acid solution of a typical electrolyte like sodium acetate (which is the one for which the most data are available) could be gained from a study of other properties of such a solution, light might be thrown also on the anomalous transference. It might be expected, for instance, that a study of freezing-point data would give some clue as to the molecular state of the solute. In the following table the freezing points of sodium acetate solutions, from the data of Kendall and Adler[15] and of Webb,[16] are compared with those calculated[17] for a perfect *undissociated* solute in acetic acid.

TABLE 5.—Freezing points of acetic acid solutions

Mole per cent solute....	*0*	*0.3*	*0.5*	*1*	*2*	*3*	*4*	*5*
Ideal solute, °C........	16.60	16.42	16.30	16.00	15.40	14.79	14.17	13.55
Sodium acetate, °C.	16.60	16.45	16.36	16.07	15.45	14.77	14.10	13.47

Evidently, despite the dissociation of sodium acetate into ions, the freezing-point depressions throughout this range are almost the same as the ideal values; for ammonium acetate the corresponding depressions are even smaller. While it is apparent that we have here a state of affairs quite different from that existing in aqueous solutions, the correct interpretation of the data is by no means obvious, since, due to the very low dielectric constant of the solvent, large interionic forces are present, and these may be mainly responsible for the deviation from the behavior of an ideal ionized solute. Widely divergent views have been expressed as to the molecular state of sodium acetate in these solutions. Thus Walden[18] apparently regarded this compound as being only slightly dissociated into ions and probably associated to some extent into polymeric molecules. Webb,[16] on the other hand, assuming the electrolyte to be practically completely dissociated, accounted for the low freezing-point depressions in terms of interionic forces as calculated according to the Debye-Hückel theory. A viewpoint intermediate between

16. Webb, J. Am. Chem. Soc., 48, 2263 (1926).

17. From the equation $\ln N_1 = \frac{\Delta H}{R}\left(\frac{1}{T_m} - \frac{1}{T}\right)$, or $T = \frac{T_m}{RT_m/\Delta H \, . \ln N_1}$, where T is the freezing point of the solution, T_m that of pure acetic acid, 289.7°, ΔH the molal heat of fusion of acetic acid, 2,780 calories (de Visser, Rec. trav. chim., 12, 101 [1893]), and N_1 the mole fraction of acetic acid; R has its usual significance. On substituting the numerical values and changing to common logarithms, this equation takes the form $T = \frac{289.7}{1 - 0.4771 \log N_1}$.

18. Walden, "Molekulargrössen von Elektrolyten in nichtwässerigen Lösungsmitteln," Dresden and Leipzig, 1923, p. 132-5.

these extremes was adopted by Hall and Werner,[19] who concluded, on the basis of electrometric titration and dilution curves, that although sodium acetate is to be classed among the "stronger" bases in acetic acid, yet it cannot be regarded as being completely dissociated in the usual sense, since its basicity changes with dilution as though the electrolyte obeyed the dilution law.

It is, of course, possible, by thermodynamic treatment which does not require any hypothesis as to the actual molecular state of the solute,[20] to calculate the activity coefficient of the electrolyte from the freezing-point data. This having apparently not been done hitherto, we have made the calculation by the method of Randall[21] for several concentrations, with the results shown in Table 6.

TABLE 6.—Activity coefficient of sodium acetate in acetic acid

Molality	0.001	0.01	0.1	1.0
Activity coefficient	0.366	0.121	0.032	0.010

Our knowledge of acetic acid solutions is, in our opinion, as yet inadequate to provide a satisfactory explanation for these very low activity coefficients, or even to permit a certain decision among the conflicting viewpoints as to the molecular state of this electrolyte. Little additional light is thrown upon the question by the available conductivity data for sodium acetate,[22] which show a minimum value of the equivalent conductance at a concentration of about 0.05 M. It is evident that any attempt to calculate the degree of dissociation from conductivity data by the classical method of Arrhenius would be quite futile. On the other hand, it appears that interionic attraction theories alone, based upon the assumption of practically complete ionization, might be equally inadequate to deal with this case, since some sort of ionic association almost certainly occurs. The very recent work of Fuoss and Kraus[23] seems to indicate, however, that a better understanding of the state of electrolytes in solvents of low dielectric constant may eventually be attained by means of a further study of conductance data for dilute solutions by a method derived from both viewpoints.

19. Hall and Werner, J. Am. Chem. Soc., 50, 2367 (1928); see, also, Hall, Chem. Reviews, 8, 208 (1931).

20. See Randall and Allen, J. Am. Chem. Soc., 52, 1814 (1930).

21. Randall, ibid., 48, 2512 (1926). The value of λ was taken as 3.604, and the Debye-Hückel limiting law, in the form $\log \gamma = -25\, m^{\frac{1}{2}}$, was used as an aid in determining the limiting value of $j/m^{\frac{1}{2}}$ at infinite dilution.

22. Hopfgartner, Sitz. Akad. Wiss. Wien, 120, II, 1024 (1911); Longsworth, Thesis, University of Kansas, 1928.

23. Fuoss and Kraus, J. Am. Chem. Soc., 55, 1919, 2387 (1933).

It should be mentioned also that Freed and Kasper,[24] on the basis of magneto-chemical studies, question the validity of the transport number as a criterion of the formation of complex ions, believing that anomalous transference may eventually be accounted for on the basis of a hypothesis of ionic clusters. For the present we can say only that although the abnormal transference numbers of sodium and ammonium acetates *may* be due to the presence of complex ions, we have no positive evidence that this is the case.

SODIUM-ZINC AND AMMONIUM-CUPRIC ACETATE SOLUTIONS

Because of the amphoteric properties exhibited by zinc and cupric acetates in acetic acid, it was expected that some indication might be found of the migration of zinc or copper toward the anode. This appeared particularly likely in the presence of a large excess of acetate ion (that is, in solutions containing high concentrations of sodium or ammonium acetate), in view of the frequent occurrence of such reversed transference in aqueous solutions under similar conditions.[25] However, the data of Tables 3 and 4 show a decrease in zinc or cupric acetate in the anode compartment in every case, and hence give no evidence of reverse migration. The determination of the conventional transport numbers for zinc or copper in the corresponding acetates, under these conditions, would have required a knowledge of the distribution of the current between the two bases present together in each solution, and even an approximate calculation of such distribution was impossible. Thus, in a solution of sodium and zinc acetates, the fraction of the current carried by the zinc acetate would depend both on the relative concentrations and on the relative conductivities of the two bases; but no conductivity data for zinc acetate are available, and in fact this compound is so slightly soluble that solutions of the concentration here used, but containing no sodium acetate, could not possibly be prepared. However, the data sufficed, in every case, for the calculation of the fraction of the *total* current carried by the less positive cation.

In figure 4 the fractions apparently transported by ammonium and by copper in the mixed acetate solutions are plotted against the concentration of ammonium acetate. It is evident that the transference of copper towards the cathode decreases with increasing concentration of ammonium acetate, but this result would necessarily follow

24. Freed and Kasper, ibid., 52, 2632 (1930).

25. McBain and Van Rysselberge, J. Am. Chem. Soc., 50, 3009 (1928), and 52, 2336 (1930).

from the increasing fraction of current carried by the latter base. In fact, both zinc and copper, in the mixed solutions, appear to carry a far larger share of the total quantity of electricity than would be expected from their relative concentrations. These experiments, then, give no evidence of the presence in the solutions examined of complex anions containing either copper or zinc. In view, however, of the highly anomalous nature of the conductance phenomena even in solutions of single salts in this solvent it can scarcely be concluded that the existence of such metallate ions is definitely disproved, and the nature of amphoterism in acetic acid solutions remains a subject for further study.

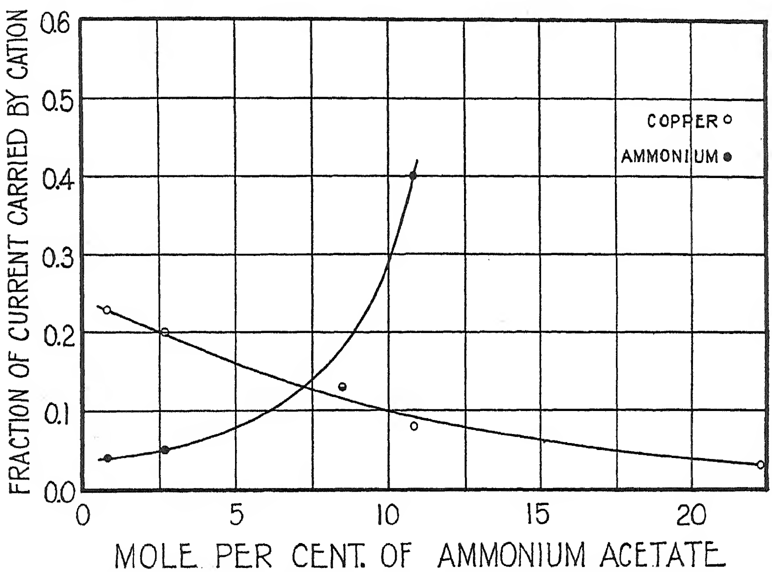

FIG. 4. Transference of copper and of ammonium in ammonium cupric acetate solutions containing 0.3 mole per cent of cupric acetate.

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The Effects of a Minimal Lethal Dose of X-Rays upon Chick Embryos

H. ERNEST CROW, Friends University, Wichita, Kan.

ABSTRACT: Chick embryos of 28, 48, 60, 75, 96 and 120 hours of incubation were exposed to unfiltered X-rays with the current set at 22 a. and 90 v. for 15 minutes at a distance of 18 cm. This dosage was found to be the minimal amount that would cause death of the chicks in 15-20 hours. The different tissues and organs of the chicks were carefully studied in serial sections at periods from 20 minutes to 20 hours after raying. Effects became observable in about two hours and became more pronounced with the passage of time. All the tissues of the body were affected, but the greater modifications occurred in the blood and nervous systems. Separation and fraying of cell layers, breaking of limiting membranes and capillary walls, accompanied by the accumulation of disorganized cellular debris within the brain and other cavities, and extensive hemorrhages, were common, general effects. In dividing cells the principal modifications were inhibited mitoses, clumped chromosomes, unequal divisions, pycnosis and fragmentation of chromosomes. In other cells nuclear and cytoplasmic substances were separated into large, irregular granules and clear vacuoles, cell walls were broken, cytoplasm oozed from the ends of cells and nuclei became shrunken. The characteristic affinity of chromatin for Iron Hæmatoxylin stain was much disturbed after a few hours, a faded gray or almost no color being common.

INTRODUCTION

IN the three and one-half decades since the discovery by *Röntgen* of the rays which bear his name, or popularly called X-rays, much interest has grown around the use of X-rays in the treatment of disease. Only a very limited number of workers have used X-rays in experimental research to determine the effects produced upon the cells rayed. The greater number of these have confined their attention to tissues grown in vitro. The embryo of the chick is a favorite experimental animal, yet only a few workers have used it

for the study of the effects of X-rays upon the living animal. It was with a desire to investigate the effects of X-rays upon the tissues of the young chick embryo that this work was undertaken.

The experiments herein recorded have for their object:

To investigate the effects of single exposures of unfiltered X-rays of constant dosage upon chick embryos of different ages.

To discover, if possible, what tissue, if any, is more affected than others.

To learn what cellular changes take place as a result of the X-rays.

ACKNOWLEDGMENTS

To Prof. H. H. Lane, head of the Department of Zoölogy, University of Kansas, under whose direction the present work was done, for his kindly interest and helpful suggestions, the author wishes to express his sincere gratitude. Also, he wishes to thank Prof. C. V. Kent, professor of physics in the University of Kansas, for his help in the use of the X-ray apparatus.

HISTORICAL

Rolleston (75) has summarized in a recent paper the growth in interest in X-ray effects on living tissues as well as showing their harmful effects upon man.

Experimental study of effects of X-rays on living cells was begun by Perthe (66), who exposed the eggs of *Ascaris megalocephala* to X-rays and found delayed development of body and the production of individuals abnormal in some parts of the body. In 1904 Gilman and Baetjer (35) exposed hen eggs to X-rays for short periods on successive days and noted, at first, a slight acceleration of development, followed by production of abnormalities, deformities, retardation of eyes and adherence of membanes to the body of the embryo.

Hartman (41) in 1920 exposed frog larvæ to X-rays and found reduction in number of leucocytes; while retardation of growth and reduction of cell number in lymphoid tissue in rats and mice when exposed to X-rays were observed by Cramer, Drew and Mottram (27), in 1921. Jolly (49), 1924, confirmed their results in experiments on guinea pigs where a difference in susceptibility to X-rays was noted between bone and lymphoid tissues; and in 1927 Brambell, Parkes, and Fielding (18) caused sterility in the adult mouse by raying its ovary, and in the young by exposure before birth.

Wright and Bulmar (93) in 1929 found rabbits and cats were killed by X-rays, but the former requiring twice the time of exposure for the effect to be lethal.

Eggs of frog, rayed by Ancel and Vintemberger (5) 1924, did not show effects immediately, but death occurred in a few hours after gastrulation began. The same authors (14), 1928, found a given dosage affected frog eggs to a greater extent when employed as a single dose than when spread over two or more exposures.

Specific effects upon cells were reported by Ancel and Vintemberger (14), 1928, on frog eggs. It was found that the time of least susceptibility was when the egg was in a state of nuclear repose. Vintemberger, 1928, by careful and ingenious experimentation on frog eggs proved that the nuclei are very susceptible to X-rays and the cytoplasm very little, if at all, affected; this confirmed the results secured by Albert and Politzer (3), 1924, on Ambystoma larvæ where the X-rays affected the arrangement, splitting and distribution of chromosomes. Chick embryos have proven good materials for experimental work. Ancel and Vintemberger (8), 1924, in their work on chick embryos found support for the prevalent idea that cells are more sensitive to X-rays when in mitosis. Heim (42), 1927, raying eggs before they were laid and embryos at various ages, found in all cases growth retarded and marked eye and brain defects, the effects varying inversely with the age. In 1922 and 1926 Colwell, Gladstone and Wakely (24-25), by subjecting chick embryos of various ages to daily doses of X-rays, produced marked degeneration of all tissues, but especially epithelial, nerve and blood tissues. By single doses of different intensity Strangeways and Fell (80) produced similar degenerative effects to those produced when heavy doses were used, but there was a partial recovery from lighter doses. Yamamoto (94) found inhibition, retardation or modification of whole or parts of organs, and death in most cases resulted when chick embryos were exposed to sufficient dosage of X-rays. In his report only gross external modifications are described.

MATERIALS USED

The chick embryos used are in seven series, *i. e.*, rayed at seven different ages, as follows:

Series I	rayed at 0	hours of incubation
Series I	rayed at 100	hours of incubation
Series I	rayed at 110	hours of incubation
Series I	rayed at 140	hours of incubation
Series I	rayed at 160	hours of incubation
Series II	rayed at 28	hours of incubation
Series III	rayed at 48	hours of incubation
Series IV	rayed at 60	hours of incubation
Series V	rayed at 75	hours of incubation
Series VI	rayed at 96	hours of incubation
Series VII	rayed at 120	hours of incubation

With the exception of Series I, in which time of exposure was variable, all were exposed to the X-rays for the same length of time, *i. e.*, fifteen minutes. This is the time that, for a given distance from the target, and at a certain dosage, was the minimal lethal dose.

TECHNIQUE OF IRRADIATION

The apparatus employed was one of the coils fitted with a Coolidge tube used in the physics department of the University of Kansas. The current was set at 22 a. and 90 v. The eggs were placed at a distance of 18 cm. from the Tungsten target during time of raying without any filter. All the time the eggs were out of the incubator they were kept well wrapped in layers of warm cotton in order to avoid, as far as possible, any change of temperature. After the period of raying the eggs were returned at once to the incubator, where a temperature of 39° C. was maintained.

HISTOLOGICAL PREPARATION

After their respective periods of incubation the eggs were opened, a hole an inch in diameter being made on the side toward the larger end, and part of the albumen pulled out and cut off. Careful observations were made of the living embryos, noting any reddening on the body of the blastodermic disc; attention was paid to the heartbeat and to any other features that might appear noteworthy. Then, by means of a capillary pipette, several cubic centimeters of Bouin's fixative were injected beneath the body, thereby lifting it slightly from the yolk. A generous amount of the solution was also poured over the surface of the embryo. The fixing solution

was replaced as needed, for it was believed best partially to fix the embryo in situ in order to minimize the disturbance in the distribution of the blood. In this way the chicks were fixed for a period of ten to twenty minutes. Then the embryo and much of the blastodermic disc were cut around and loosened from the remainder of the egg, and carefully floated off and transferred directly to a dish of the fixing solution. The embryos were allowed to remain in this solution from 2 to 18 hours according to size; they were then washed for a few minutes in distilled water to remove the excess fixative and, as rapidly as safety would permit, carried through ascending grades of alcohol to 70 per cent, where they were held, with frequent changes, until the alcohol was no longer colored. In the same strength of alcohol they were preserved. Subsequently those which were to be sectioned were passed through ascending grades of alcohols to absolute. They were then cleared by gradual addition of cedar oil to the alcohol, until the alcohol was completely replaced by the oil. After passing through two changes of oil the embryos were placed in a paraffin bath for embedding. After embedding they were cut in serial sections seven or ten micra in thickness, and subsequently stained in (*a*) hæmatoxylin and counterstained with eosin, or (*b*) iron hæmatoxylin and counterstained with eosin or acid fuchsin.

After mounting in Canada balsam all of the sections were carefully examined with a Leitz binocular microscope, using 16 × oculars and 45 × objective. The finer cellular details of all tissues were studied with 16 × oculars and 95 × achromatic oil-immersion objective.

SERIES I

In series I are included all of the results of the preliminary experiments performed to determine what is the minimal lethal dose. All the chicks were exposed to the same voltage, *i. e.*, 22 a., 90 v., the distance and time being changed.

The experiments were grouped under A, B, C and D, as follows:

SERIES I

Number of individuals.	Dosage.	Distance target.	Length of exposure.	Age at time of raying.	Age opened.	Results.
GROUP A						
4	90v., 22a.	40 cm.	15 min.	0	120 hrs.	Normal development.
4	90v., 22a.	40 cm.	30 min.	0	120 hrs.	Normal development.
4	90v., 22a.	40 cm.	40 min.	0	150 hrs.	Normal development.
2	90v., 22a.	40 cm.	60 min.	0	150 hrs.	Normal development.
2	90v., 22a.	40 cm.	60 min.	0	240 hrs.	Normal development.
2	90v., 22a.	40 cm.	90 min.	0	288 hrs.	Normal development.
2	90v., 22a.	40 cm.	90 min.	0	384 hrs.	Normal development.
GROUP B						
4	90v., 22a.	18 cm.	10 min.	0	30 hrs.	Normal development.
4	90v., 22a.	18 cm.	15 min.	0	30 hrs.	Almost normal development—dead.
4	90v., 22a.	18 cm.	20 min.	0	30 hrs.	Developed very little—dead.
4	90v., 22a.	18 cm.	25 min.	0	30 hrs.	Almost no development—dead.
GROUP C						
2	90v., 22a.	18 cm.	20 min.	100 hrs.	100½ hrs.	Living.
2	90v., 22a.	18 cm.	20 min.	100 hrs.	102 hrs.	Living.
2	90v., 22a.	18 cm.	20 min.	100 hrs.	117 hrs.	Dead.
GROUP D						
8	90v., 22a.	18 cm.	75 min.	110 hrs.	135 hrs.	Dead about 112 hours.
3	90v., 22a.	18 cm.	60 min.	140 hrs.	143 hrs.	Dead.
3	90v., 22a.	18 cm.	45 min.	140 hrs.	143 hrs.	Dead.
3	90v., 22a.	18 cm.	30 min.	140 hrs.	143 hrs.	Two dead, one living.
3	90v., 22a.	18 cm.	30 min.	160 hrs.	167 hrs.	Dead.
3	90v., 22a.	18 cm.	25 min.	160 hrs.	167 hrs.	Two dead, one living.
3	90v., 22a.	18 cm.	20 min.	160 hrs.	167 hrs.	Two dead, one living.

CONCLUSIONS

Lethal effects do not appear even after long exposure at a distance of 40 cm.

Growth is not retarded or accelerated by exposure of as long as 90 minutes at a distance of 40 cm.

Growth is stopped and death occurs within a few hours after exposure of 20 minutes or more at a distance of 18 cm.

Death of embryo does not occur for about 20 hours after exposure of 15 minutes at 18 cm.

Exposure of 10 minutes at 18 cm. produced no effects.

SERIES II TO VII

In the following pages each stage has been given two numbers, separated by a hyphen, by which it will be known in referring to it either in discussion or in explanation of the plates. The first number gives the age at which the chick was exposed to the X-rays; the second figure gives the age of the chick at which it was killed and studied. Thus 28-34 means the chick was 28 hours old when rayed and 34 hours old when killed.

In the series following, all the embryos which were exposed to the X-rays received the same dosage. The current was set at 90 v. and 22 a.; the time of exposure was 15 minutes, with the eggs placed 18 centimeters from the target.

The following tables present in condensed form the effects observed in the chick embryos included in series II to VII. No record is given of the conditions found in the control specimens. Without exception they all showed normal conditions in growth, mitosis, chromosome arrangement and staining qualities.

Series II

In series II the control and rayed embryos have been carried, side by side, through all the steps from the time the eggs were placed in the incubator until the sections were mounted, except for the short time when the latter were being exposed to the X-rays. During that short period the control specimens were taken from the incubator and placed beside the X-ray apparatus, yet always completely shielded from the X-rays. The rayed specimens have shown, without exception, modifications and abnormalities, which have increased in extent and magnitude with the length of time after raying. The control specimens have shown normal conditions in every tissue. It appears, therefore, that whatever modifications have occurred in the rayed embryos, have been caused only by the X-rays.

SERIES II

Age at time of raying and observation, hours.	Ectoderm.	Neural tube and optic vesicles.	Entoderm.	Mesoderm.	Blood.
28-30........	Few mitoses..	Few mitoses; normal appearance.	No apparent change in cells; few mitoses.	No visible change; few mitoses.	Few mitoses.
28-34........	Rare mitoses; stain is poor.	Rare mitoses; cytoplasm more granular.	Rare mitoses; stain is dim; greater granulation.	Rare mitoses; some chromosomes clumped; more granulation.	Some clumping of chromosomes in the rare mitoses; some granulation.
28-45........	Much separation of layers; cells broken and frayed; large irregular granules and clear spaces; chromosomes indistinct.	Debris within brain vesicle; cells stain dimly; chromosomes indistinct; some granulation and vacuolation.	Lining of foregut broken and frayed; some debris within cavity; few large granules in cytoplasm; chromosemes indistinct and apparently dissolved in cytoplasm in early mitoses; some nucleishrunken.	Cytoplasm often shrunken about nuclei, granular, large vacuoles, apparent dissolution of chromosomes in dividing cells.	Karyosomes prominent; stain dim; granules large; many cells broken; very rare mitoses; all abnormal; chromosomes partly dissolved; two cells with tripolar spindles.

CONCLUSION

Raying effects are most marked in nerve tissue.

Cytoplasm becomes more granular and nuclei less distinct after raying. Mitoses are not stopped suddenly, but, if in division, a cell goes on and completes it. Probably no cell begins and completes division after raying.

SERIES III

In series III the embryos which have been used as controls have been kept under the same conditions as the rayed specimens, save only that they were not exposed to the X-rays. Even during the short time when the rayed specimens were being exposed to the X-ray, the controls were beside the X-ray apparatus, but fully shielded from the rays. Through fixation, dehydration, clearing, embedding, staining, mounting, etc., the control and the rayed embryos have been carried under as near identical conditions as it is possible to secure. If faulty technique had been the cause of modifications and degeneration in one set of embryos it should have shown similar changes in the other group. In all of the irradiated embryos these modifications, as given in the preceding pages, have appeared, while in not a single control specimen have any than normal conditions been found. In view of all the evidence only one conclusion could be made, namely: the X-rays have been the cause of the modifications occurring in the irradiated embryos.

CONCLUSION

The effects of the X-rays are shown by the nervous tissue in which there occur: separation of limiting membranes, breaking of neural wall in places, and partial filling of canal with disorganized cellular debris.

The number of cells in mitoses decreases rapidly, none occurring after about six hours. A few show chromosomes somewhat clumped. The cytoplasm and nuclei show granules which appear to increase in size with degeneration of the cells.

Fraying of epithelium occurs in many places.

Debris accumulates within cavities or tubes of the body.

Tissues stain less well.

SERIES III

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
48-52.......	Very few cells dividing; chromosomes abnormal; cytoplasm granular and vacuolated.	Rare mitoses not clear-cut; granulation and vacuolation disorganized material in brain cavity.	Mitoses rare with some condensation of chromosomes; some fibrin-like material within vesicle.	Few mitoses with some condensation of chromosomes; stain not definite; some material in the vesicle.	Few mitoses with some clumping of chromosomes; some fibrinoid material in pharynx.	Mitoses are infrequent; karyosomes prominent; large granules.	Cytoplasm contains large granules; cell wall broken in many cells; some nuclei fragmented; few mitoses; in some cells chromosomes are clumped.	Few cells dividing; slight clumping in few cells.
48-54.......	No increase in size; separation in many places; granulation; few mitoses with condensed chromosomes.	Dividing cells swollen, a few bursted with contents passing into cavity; other debris within brain cavity.	Mitoses rare; some clumping of chromosomes; debris in vesicle; stain, gray in color.	Rare mitoses; some chromosome condensation; stain gray; debris in the cavity.	Infrequent mitoses; some chromosome condensation; debris in pharynx; stain poor.	Very few cells in division stages; some clumping of chromosomes; stain is not sharp.	Karyosomes prominent; stain not sharp; rare mitoses; some with condensed chromosomes; a few cells broken.	Staining not good color; large granules in cytoplasm; very few mitoses.
48-56.......	Much separation; large granules and vacuoles; walls dim; rare mitoses.	Canal nearly filled with disorganized cellular mass; limiting membrane broken and frayed; stain very poor; rare mitoses.	Much debris in vesicle; poor differentiation of stain; granules large; very rare mitoses; compact chromosome arrangement.	Mucn material in vesicle; wall broken; stain poor with little differentiation; few cells dividing show chromosomes poorly defined.	Much debris in cavity, some fraying of inner layer; vacuoles prominent in some cells; no mitoses; gray stain.	Some shrinking of cytoplasm; mesothelium separated and broken in some places; absence of mitoses.	Much granulation; poor differentiation; few broken cells; very rare mitoses; some chromosomes fragmented.	Cell walls poorly defined, some broken; no cells dividing.

SERIES III—CONCLUDED

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
48-60.......	Much separation and degeneration; stain dim; some cells broken; granules large; karyosomes fragmented; no cells dividing.	Canal almost filled with broken cells; membrane broken and frayed; no cells dividing; large granules resemble broken chromosomes.	Vesicle filled with cells and granules; exudations from walls; no mitoses.	Cellular debris in vesicle; broken walls; large granules and vacuoles; karyosomes irregular; no cells dividing.	Pharynx cells broken and frayed; debris in cavity; large irregular granules; no cells dividing cells; stain poorly.	Cytoplasm shrunken and granular; myocœle filled with material; walls leaking; no cells dividing.	Large cytoplasmic granules; walls broken; nuclear material condensed upon wall; cells shrunken and fissured; no mitoses; poor stain.	Loss of affinity for stain; granules large; no mitoses.
48-62.......	Layers separated and frayed; almost no stain; cells almost structureless with few large granules; no cells in division.	Much debris in canal; wall of brain broken; no cells dividing; stain is a dull gray; much disorganization.	Development inhibited; small vesicle filled with debris; walls broken and frayed; no cells dividing; stain poor.	Limiting membrane frayed with cells forming debris in vesicle; large vacuoles and granules; some karyosomes are fragmented; no cells dividing.	Much debris in gut cavity; wall broken and frayed in many places; much degeneration; no mitoses.	Much degeneration; walls leaking and forming debris in cavities; cytoplasm granular; gray stain; no cells in division.	Much fragmentation and breaking of walls; karyosomes fragmented; no cells dividing; poor staining; differentiation.	Much degeneration of cells; all appear faded gray; no cells dividing.

SERIES IV

The irradiated embryos of this series have had controls checked against them at every point from beginning of incubation to the mounting finally of the sections. Only in the item of irradiation has there been a difference in treatment. Any changes occurring in specimens which have been irradiated and not appearing in the controls could be interpreted as having been caused by the X-rays. In the report on the embryos constituting series IV, given in the following pages, there is given a recital of the changes and modifications which were found in the irradiated specimens. With very great similarity in the extent of the effects, the type of modification and the time of their appearance, these changes have appeared in all the individuals which were exposed to X-rays. Not one of the controls showed any of the marked modifications so characteristic of the irradiated specimens, but all were normal in every way. The X-rays have been, without doubt, the cause of all of the destructive changes which have appeared in the embryos irradiated.

CONCLUSION

Exposure to X-rays has caused the accumulation of much disorganized material within the cavity of the brain and cord, the optic vesicles, pharynx and cœlom.

There is a rapid decrease in number of cells dividing, only a few showing after six hours. Slight condensation of chromosomes into a clump shows in a few cells.

The granules in the nuclei and cytoplasm have become more prominent.

The cells do not retain the stain well.

SERIES IV

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
60-62.......	Some separation of layers; increase in vacuoles and granules; mitoses normal in number and arrangement.	Little change; limiting membrane broken in few places; little fibrinoid material in cavity, mitoses less than normal number.	Some material between coats; not many cells dividing; karyosomes resemble condensed metaphases.	Cell walls indistinct; no mitotic figures.	Normal appearance in most cells; slight condensation of chromosomes in the few cells dividing.	Slight leaking of mesothelial membrane; very few cells dividing.	Pronounced granulation; almost no mitoses; chromosomes condensed; a few nuclei are fragmented.	Slightly greater granulation; no cells dividing.
60-64.......	More separation of layers; stain not retained well; vacuoles common, few cells dividing, chromosomes not definite.	Inner limiting membrane broken in places, and cells passed into brain cavity; mitoses few; chromosomes in few slightly clumped; stain not well retained.	Distinct separation of coats with space filled with disorganized cells and fibrin-like substance; no cells dividing; cytoplasm oozing from inner end of lens cells.	Cells indistinct; a very few cells in division; some with clumped chromosomes; vesicles filled with fibrinoid material.	Pharyngeal wall broken in few places; cells passing into cavity; cytoplasm granular; few cells dividing.	A little fraying of walls, and some debris in the cœlom; few cells show normal chromosome arrangement.	Prominent granules in cytoplasm; nuclei shrunken, wrinkled and fissured; rare mitoses; stain less sharp.	Large granules; rare mitoses; individual chromosomes cannot be distinguished because of compact shape.

SERIES IV—CONCLUDED

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
60-66......	Separation of layers in many places; many large granules in cells, no cells in division.	Much degeneration of brain wall; inner limiting membrane broken frequently; much debris in cavity; nuclei indefinite; karyosomes broken and fragmented; very rare mitoses; chromosomes slightly clumped.	Coats widely separated and broken; vesicle filled with debris; much congestion of blood around eye; lens cavity filled with fibrin-like material; no cells dividing.	Much material within vesicles; walls leaking badly; some nuclei apparently dissolving; no cells dividing; stain poor.	Cavity of gut filled with debris; wall broken in many places; cell walls indefinite and poorly stained; no mitoses.	Mesothelium broken and frayed; cells oozing cytoplasm into cœlom; stains poorly; large granules; rare mitoses.	Many fissured, wrinkled, broken and fragmented cells; nuclei irregular and fragmented; large granules of many shapes, some like chromosomes; very rare dividing; cells show clumping of chromosomes; spindles hardly visible.	Some leaking of walls; debris inducts, indefinite cell walls; granules prominent in nuclei, and irregular in shape; no mitoses; loss of affinity for stain.

SERIES V

In all the steps of preparation of the embryos for microscopic study, control and irradiated specimens have been subjected to as nearly the same conditions as possible, except in the matter of irradiation. Under these conditions all the control specimens have shown normal development and cell structure, while the irradiated embryos have in every case shown modifications and degeneration. In all control specimens mitoses, with clearly defined chromosomes, have been found abundant, but in irradiated embryos the number of mitoses decreases rapidly till after six hours none may occur. In the controls the chromosomes occur regular in arrangement and definite in outline, but in the irradiated specimens clumping of chromosomes occurs frequently, and in a few cells the chromosomes are so disorganized as to be little more than a granular mass of irregular shape. In the control embryos the cytoplasm and nuclei rarely contain prominent granules; but in a few hours after exposure to X-rays embryos show very large granules in many cells. The separation of epithelial membranes from underlying mesoderm or the breaking of these membranes does not occur in control specimens. Cellular exudations, which occur so prominently in the later stages projecting into the cavities of the brain, cord, gut and urinary ducts, and into the cœlom and the vesicles of the sense organs, are not found at any place in the control specimens. Hemorrhages occur in embryos a few hours after irradiation. These become greater with the passage of time, until in the 75-94 specimens all except one individual, which was little affected by the X-rays, showed widespread areas involved. In the controls not one showed any hemorrhages whatever. The dark-blue color and clear differentiation characteristic of tissues stained with hæmatoxylin were found in every control specimen, while in those irradiated the characteristic color, after a few hours, did not appear; in fact, the affinity for all stains employed became less with the passage of time. Since great changes have occurred in the structure of the cells, as shown by the granules, vacuoles and fragmentation, it seems reasonable to suppose that the chemical constitution of the cells may have been altered, and, if so, then the change in staining reaction may be this expected result.

Inasmuch as all the irradiated specimens have shown destructive modifications which have become greater with the passage of time after irradiation, and since in not one of the control speci-

mens did any of the modifications occur, proves, without reasonable doubt, that the X-rays have caused the destructive changes.

CONCLUSION

Few mitoses are found four or more hours after irradiation.

There is much material in the neural canal, in the vesicles of the eye, cœlom, and lumina of digestive and urinary systems. This material varies in amount with the length of time after raying.

The effects seem to be general rather than local and do not make their appearance for some time after irradiation.

All the effects of raying appear to be destructive, *i. e.*, no acceleration occurs, and, given enough time, all tissues show degeneration. This consists of separation of epithelial membranes, appearance of granules, and vacuoles in the cytoplasm, loss of affinity for stains, so that the nuclei and cytoplasm are poorly differentiated, and in the cells dividing often a condensation of chromosomes occurs.

There appears to be a difference in degree of susceptibility, one specimen of 75-79 showing a few mitoses, others none.

In 75-94 stage one chick, which was much older than the others, showed little effects of raying, having recovered enough that many cells were in division.

SERIES V

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
75-78.......	A little separation of layers; some fragmentation of a few karyosomes; stain not sharp; few mitoses; some chromosome groups; compact spindles invisible.	Lack of sharpness in cells; small amount of material in cavity; clouds of cytoplasm project from cells into canal; few mitoses with little sharpness.	Small space between coats partly filled with debris; lens also has material in vesicle; some increase in granulation; few cells dividing.	Some breaking of inner membrane where cells are added to debris in vesicle; few cells dividing.	Little effect on cell appearance; clouds of cytoplasm oozing from cells of hind gut; a few cells in division apparently normal.	Not good differentiation; karyosomes fragmented in some cells; amitosis in few cells; not many cells dividing.	Many small cells; large cells often have fragmented nuclei; large granules abundant; few cells dividing.	From many cells, cytoplasm has escaped into lumen of duct or tubule; a small number of cells dividing these often bulging into lumen.
75-79.......	Much like 75-78; few large granules; no cells dividing; one specimen, a few mitoses.	Spaces in brain wall from which cells have passed into canal; cell shapes indefinite; stain not sharp; few cells dividing in one specimen, none in others.	Coats widely separated and space filled with disorganized material; cell walls indistinct; lens vesicle filled with debris; long cells shrunken; chromosomes in the rare mitoses clumped.	Inner membrane broken; cytoplasm and nuclei oozed into vesicle; stain poorly differentiated; large granules; rare mitoses; some clumping of chromosomes.	Gut in most places filled with material; wall broken in places; liver and blood cells mixed; few cells in division, none normal; some fragmenting of chromosomes.	Much like 75-78 material in cœlom; clouds of cytoplasm passing from cells; cells in head mesenchyme shrunken.	Hemorrhages in many places; granules large and irregular, often condensed upon cell wall; many cells broken and others with fragmented nuclei; rare cell divisions; a few appear as chromosomes melted together.	Much as 75-78; a few tubules broken; one chick only showed mitotic stages; slight clumping of chromosomes appeared.

SERIES V—CONCLUDED

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
75-94......	Much separation of layers; a few appear swollen as if a prophase had been aborted; in such, no karyosomes appear; large granules and vacuoles; no mitoses; one specimen several cells dividing.	Great hemorrhages in area surrounding brain have broken wall, and material in cavity contains blood cells; wall is folded and separated in places; spinal canal filled; no cells dividing; very dim gray stain; one chick had more the appearance of those of 75-78 stage, it was 10-15 hours older.	Great hemorrhages around eye causing separation of coats and filling of vesicles; wall broken frequently; large granules grouped around cell wall; shrinkage in lens cells; no cells dividing except in one specimen.	Wall folded and broken; vesicle filled; nuclei irregular; karyosomes much faded; no cells dividing.	Pharynx walls broken; cells in cavity debris; poor differentiation; nuclei of many cells shrunken and angular; large granules; cells of liver and blood mingling; no mitoses, except in one specimen, where some cells appear to be dividing by amitosis.	Stain dim; cells in mesenchyme shrunken and irregular; mesothelum often broken and frayed; debris in cœlom, one chick showed a few cells dividing; all small and compact, others none.	Great hemorrhages; stain not uniform; dim; many cells irregular; some shrunken, others with fragmented or no nuclei; appear as if nuclei were dissolved in cytoplasm; one specimen had few cells dividing, all others none; chromosomes showed condensed arrangement.	Tubules broken in many places, and lumina filled with blood and other cells; stain is poor; no mitoses except in one chick, and but few there.

SERIES VI

In this as well as in all the other series, irradiated specimens and controls have, in their preparation for microscopic study, been carried as near side by side as possible. In the long staining process not only have both received exactly the same treatments, but often a slide on which are sections of an irradiated embryo, and one on which are sections of a control, have been carried through the different staining, washing and dehydrating jars, back to back. In this way, if effects due to faulty technique appear in one they would appear also in the other. In the irradiated specimens, except those in the 96-20-minutes stage, which were killed before effects became visible, there have occurred such modifications as have been reported at length in the preceding pages. Not one irradiated specimen killed two hours or more after irradiation was normal, while all the control specimens were normal in every respect. It is very evident that the many degenerative changes that occur in irradiated embryos are due wholly to the action of X-rays.

The effects of X-rays on chick embryos of different ages, as reported in this paper, have always appeared as degenerative modifications. These have grown in magnitude with the passage of time after irradiation. In the 96-20-minutes stage an attempt has been made to discover how soon effects of irradiation appear. In this stage the embryos were killed twenty minutes after exposure to the X-rays. These showed such minor changes that it could not be determined whether they were caused by the X-rays or were merely individual variations. Two hours after irradiation modifications became apparent and grew greater each hour.

It appears that cells are affected at the time of irradiation, but there elapses a period in which no effects are visible, but which become manifest at the end of that time. There is doubtless produced within the cellular substance by irradiation chemical changes which cause serious disturbance of the metabolic balance, the result of which may be seen in the formation of granules, vacuoles and chromosome clumps and fragmentation of nuclei and the breaking up of whole cells.

CONCLUSION

The effects of raying are general rather than local, and degenerative changes occur in all tissue, but they become visible first in the nerve tissue and sense organs.

Separation of retinal coats, limiting membranes of the brain and

cord, the mesothelium and epithelium, occurs. All of these occur over greater areas with the passage of time after irradiation.

Cellular differentiation becomes less with time, the cytoplasm and nuclei becoming more granular and vacuolated.

Mitoses have not been affected in twenty minutes, but are reduced in number in two hours, and in four hours no new figures have occurred. A few of the figures have their chromosomes condensed into a clump.

Degenerative material accumulates in the neural canal, vesicles of the sense organs, alimentary canal, urinary lumina and cœlom.

Great hemorrhages occur after a few hours, probably causing much of the debris within body cavities and distortion of walls and membranes.

SERIES VI

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
96-20 min...	No gross changes; number of mitoses about one-half the number in control specimen.	Apparently normal; number of mitoses, one-half control; may be normal number.	No changes in structure; small number of mitoses.	Slight separation of inner limiting membrane.	Scant amount of fibrin-like substance in lumina of lung buds and œsophagus and cells in pharynx; mitoses about one-half normal number.	No effect apparent; number of mitoses smaller than control.	Fewer cells in division than control.	Little fibrin-like material in ducts; few mitoses.
96-98.......	Separation of layers in few places; some cells shrunken; few mitoses.	Outer limiting membrane separated in few places; some debris within brain; few mitoses and slight clumping of chromosomes.	Slight separation of coats; from lens cells cytoplasm oozes into vesicle; slight condensation of chromosomes in the few mitoses.	Stain not clear; chromosomes not well separated or distinct in the small number of mitoses.	Debris in cavity in most places; number of mitoses decreased; some chromosome plates compact.	Some loss of affinity for stain; mesothelium lifted and broken; material in cœlom; cytoplasm granular; nuclei of many cells shrunken; few mitoses.	Veins and capillaries gorged; small-sized cells; stain poorly; many large granules in other cells; few mitoses; metaphase plates condensed.	Cytoplasm more granular and dimly stained; tubules have filled lumina; few mitoses.

SERIES VI—CONCLUDED

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
96-100......	Greater separation of layers; shrinkage of cytoplasm; many granules and vacuoles; rare mitoses; chromosomes broken.	Distinct morain of disorganized material within brain cavity; cytoplasm slightly granular, and staining dimly; rare cell divisions; some show dense mass instead of chromosomes.	Greater separation of coats than 96–98; blood cells have broken coats and partly filled space between; stain not sharp; lens cavity filled; rare mitoses.	Thin wall folded and broken; debris in vesicle; stain dim, very few mitoses, chromosomes indefinite.	Walls broken in few places; much loss of cells into lumina; liver tubules broken and mixed with blood; few mitotic cells have heavy spindles and clumped chromosomes.	Cells indistinct; stain, dark gray; membranes often broken, with cells contributing to debris in cœlom; very few cells dividing.	Hemorrhages common; stain gray; granules common; many karyosomes fragmented; individual chromosomes cannot be followed in the few cells dividing.	Much of ducts and tubules show cellular debris in lumina; granules large and gray colored; rare cell divisions; chromosomes in dense masses.
96-114......	Much separation of layers with material in space; poor differentiation; karyosomes often fragmented; no mitoses.	Much degeneration; brain cavity almost filled with debris; brain wall broken frequently; very poor, dim stain; many granules in nuclei; karyosomes fragmented in some; no mitoses.	Growth stopped and much degeneration; walls broken and folded; much debris in vesicles; more granules; nuclei indistinct and some shrunken; no mitoses.	Some stripping of wall; cellular debris in vesicle; large granules condensed upon cell wall; stain, dark gray; no mitotic figures; a few nuclei and karyosomes fragmented.	Walls folded and fissured where cells have passed into lumina; blood and liver cells mingle; granules large; nuclei fragmented; some areas almost without color; no mitoses.	Cytoplasm shrunken upon nuclei; stain, dull gray; mesothelium broken, and much material in cœlom; no cells in division states.	Great destruction and hemorrhages; cells broken or fragmented, and cytoplasm oozing out; very dim stain; granules condensed on cell walls.	Much degeneration and destruction; lumina filled; dull, gray stain, allantois affected little; no cells dividing.

Series VII

The control and the irradiated embryos, which have been studied in this series, have been handled with great care and kept under as near identical conditions as possible from the time the eggs were placed in the incubator until the sections were stained and mounted, differing only in one particular—irradiation. Those embryos which have been exposed to X-rays have shown destructive changes in every tissue, all of which have been described in the preceding pages. Very similar changes have been found in all the irradiated individuals of the other series, the degree of destruction in each series corresponding to that in other series at a given time after irradiation.

In contrast with the irradiated specimens, which have shown the destructive effects already described, the controls have, without exception, shown normal development and normal cellular structure.

With degenerative changes occurring in the irradiated embryos, and not one of the controls showing any of these modifications, only one conclusion can be made, namely: the changes in the irradiated specimens are the effects of exposure to X-rays.

CONCLUSION

Degenerative effects show mostly in the neural tissue and sense organs. All other tissues are affected somewhat later or less promptly.

Great amounts of material occur within all cavities after a few hours.

After a few hours hemorrhages are present in many of the mesenchymal areas of the body and have probably caused separation of the epithelial membranes.

All the effects of raying appear to be destructive. No acceleration of growth or activity occurs in any tissue.

No division of cells occurs four hours after the embryos have been rayed. Some of the chromosome arrangements are very compact or clumped.

The allantois is affected least of all tissues, probably because of its very thinness and consequent ease with which gaseous exchange takes place. This is in keeping with results obtained by Strangeways and Fell in 1927, who found lethal effects were due to absence of gas exchange.

SERIES VII

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
120-123	Slight separations of membranes; stain less definite and sharp; few cells in division; chromosomes in some in compact tangle.	Separation of limiting membranes in few places; fibrinoid material abundant in brain cavity; mitoses near number in control; a few show distinct clumping of chromosomes.	A little material is oozing through inner limiting membrane; granules more prominent; mitoses common; some cells show condensation of chromosomes.	Slight fraying of inner limiting membrane; mitoses almost normal number.	No structural change, stain not sharp; nuclei slightly granular; chromosomes in few cells clearly clumped.	Stain is dim, and cells poorly differentiated; mitoses one-half number in control.	Small areas of head gorged with blood; stain is not sharp in color; mitoses less than control.	Greater vacuolation of some cells; fewer mitoses and less sharpness than control.
120-126.....	Separations in many places; stain dim and gray; granules large; karyosomes fragmented in few cells; no cells dividing.	Limiting membranes widely broken and cells occupy brain cavity; no cells dividing; cytoplasm contains many large granules arranged about walls; stain gray.	Coats somewhat separated and fissured with loss of cells into vesicle; stain gray; many nuclei angular and shrunken; rare mitoses; chromosomes clumped.	Surface of wall roughened; stain, dull gray; no mitoses; some cells have granules of appearance of fragmented chromosomes.	Stomach and hind gut almost filled with debris; wall broken in several places; granules large in liver cells; the few cells in division show clumping of chromosomes; stain is dim.	Hemorrhages have distorted mesenchyme of head; some shrinkage of cells; stain is dark gray; very few mitoses; small cells show condensed chromosomes.	Great hemorrhages; poor differentiation and uniformity; many cells irregular or broken; cells with two and no nuclei occur; karyosomes are frequently fragmented; rare mitoses; distinct chromosome clumps.	Some breaking of walls, and filling of tubules and ducts; granules and vacuoles common; stain faded gray.

SERIES VII—CONCLUDED

Age at time of raying and observation, hours.	Ectoderm.	Neural tube.	Optic vesicles.	Auditory vesicles.	Entoderm.	Mesoderm.	Blood.	Urinary system.
120-140.....	Much degeneration and separation; poor stain; irregular granules; condensed on cell walls; amniotic cavity; contains cellular debris; no mitoses.	Widespread degeneration; wall of brain folded in thin areas and broken in other places by pressure of hemorrhages; very poor stain; brain cavity contains much disorganized debris; large granules and fragmented karyosomes; no mitoses.	Coats separated and broken; vesicles filled with mass of disorganized cells; granules and karyosomes indistinct; lens cells shrunken into mere lines; no cells in any stage of mitosis.	Walls fissured and broken; vesicle almost filled with cells; all dimly stained, no mitoses.	Much breaking of walls; cavity filled; blood and liver cells much mixed; color is rather uniformly gray; no cells dividing.	Most spaces filled with blood; some shrinkage of cells; nuclei of some angular, others fragmented; stain very dim; much material in cœlom; no cells dividing.	Hemorrhages crowd all tissues; cells much faded; showing little structure; many cells broken; granules condensed upon wall leaving cytoplasm clear and structureless; no cells in division.	Much breaking of walls; ducts and tubules filled with disorganized cells; very dim, faded gray stain; allantois only shows a very few mitoses; chromosomes appear clumped.

DISCUSSION

In series II to VII of this paper all factors, *i. e.*, dosage, time and distance, have been kept constant. A better comparison could, in this way, be obtained. The results have been in accord with expectations. Whether a certain dosage given all at one exposure or broken into two or more fractional parts and administered on successive days, has the same effect has been made the subject of experimentation by Gilman and Baetjer (35), who found exposures of ten minutes per day for four days produced abnormalities, deformities and retardations in chick embryos. Ancel and Vintemberger (14) observed that frog eggs exposed to X-rays showed less degree of effect for a given dose when it was spread over two or more applications than when employed as one dose; but in an earlier paper, in 1925, Ancel and Vintemberger (12) had declared that the destructive effects of raying on the chick blastoderm were not modified by dividing the dose into fractional parts. Colwell, Gladstone and Wakely (25) caused profound degeneration in tissue of the chick by doses on three and five successive days and Strangeways and Oakley (79) found similar cellular changes when a single dose of soft rays was employed upon chick choroid growing in vitro, which was confirmed by Strangeways and Fell (80) on living chick embryos one day and six days old. Yamamoto (94) made an excellent test of this idea when he exposed chick embryos of similar age to single doses and to fractional doses. His conclusions show a greater number of deaths occurred in the group exposed to one dose.

The effect of irradiation on the chromosomes was recorded for *Ascaris megalocephala* by P. Hertwig (43) as a great disturbance of the chromosome arrangement, bearing little resemblance to that of normal cell division.

Gatenby and Wigoder (34) found pycnosis, similar to the "pyknosen and pseudo-amitosen" of Politzer (68), giant cell formation, necrosis and other abnormalities. Colwell, Gladstone and Wakely (25) observed condensation of chromosomes into distinct clumps, while Strangeways and Fell (80) found pluripolar spindles and fragmentation of chromosomes.

In an earlier paper, 1923, Strangeways and Oakley (79) observed on chick tissues growing in vitro, when exposed to soft X-rays, very distinct condensation of chromosomes into clumps, which, because of this massing, could not divide, but instead broke up and disintegrated. In other cells attempting to divide, most of the chromosomes reached the anaphase or telophase, leaving the

others only partially split, and thus were made to lag behind. In still others, when hit just before entering the prophase, the breaking down of the chromosome complex did not take place till the telophase, or "daughter-cell," stage.

The findings in the present series of experiments are very much in harmony with those of the workers just cited. There have occurred metaphases in many of the embryos in which the chromosomes are condensed into quite distinct clumps (figs. 31, 75, 76, 77). A few cells show a condition where the chromatin is as one heavy cord formed into a much-tangled knot (figs. 26, 29, 34). There were found a small number of cells with tripolar spindles (figs. 10, 11) in one specimen, and in rare cases in a few other individuals. The cells having two, three or four nuclei of unequal size may be the result of such abnormal spindle formation (figs. 8, 36). A number of cells in different embryos show such unusual chromosome arrangements as to bear little resemblance to those in regular mitosis (figs. 16, 19, 28, 34). Figures 19 and 28 resemble the "pseudo-amitosen" of Politzer.

In a small number of cells in a few of the embryos the chromosomes are so widely separated and disarranged as to suggest a dispersal while in the prophase (figs. 13, 16, 38, 63).

In all embryos, four hours after being rayed, cells occur that have nuclei in various stages of degeneration (figs. 5, 9, 24, 49, 50, 55, 56, 57, 58, 59, 68, 69, 70, 71, 72, 73). In many of these the size and number of granules suggest dispersal and partial fragmentation of the chromosomes.

The work of Strangeways and Fell (80) upon the chick embryos of 20-25 hours, 6 days and 17 days is similar to that reported in this paper. Using embryos of wider age difference has not modified conditions materially. Two dosages were used by these workers, the one about double the strength of the other. With the heavier dose changes occurred somewhat more quickly and with greater destruction. The embryos, after exposure, were incubated for periods varying from none to six days. The 20-25 hour embryos, observed immediately after raying, showed no microscopic changes, but sections showed a great reduction of mitotic figures. At 80 minutes, with lighter dose, mitoses were rare; with heavier dose, absent. The general conditions of the tissues under similar exposures were, respectively, slight cellular degeneration and greater cellular degeneration.

After 24 hours a partial recovery seemed to have taken place, for

mitosis became active again, though the tissues showed abnormal mitoses, reduced growth, and degeneration. Some of the abnormal mitoses showed pluripolar spindles and others fragmentation of chromosomes. Nuclear and cellular disintegrations were present and the mesenchyme had become œdematous. In embryos exposed at six days and examined immediately there was a striking reduction of mitoses, some cells showed slight degenerative effects and the surface of the body was somewhat reddened. In 26 minutes sections showed degeneration in many cells, mitoses rare, and large numbers of cells in the delicate vascular walls breaking down. In 52 minutes dark splotches occurred in most specimens, which, on being sectioned, showed great extravasation of blood. There were no mitoses observed. After 80 minutes much crimson color of body showed. An enormous number of degenerated cells occurred in all tissues, especially in the retina and central nervous system. The color of body was due to the engorgement of the superficial vessels, the walls of which had, in many places, broken down and liberated blood into the surrounding tissues. Mitoses were very rare or absent. After 24 hours no sign of recovery could be noted. There was some hemolysis, which reddened the amniotic fluid. Most cells were degenerating and many broken down. There were no mitoses.

The results shown in this paper parallel very closely those given above as reported by Strangeways and Fell (80). The series of chicks used were of ages with shorter time intervals between, *e. g.*, 28, 48, 60, 75, 96 and 120 hours. The intervals after exposure were somewhat more variable than those of Strangeways and Fell (80). The degenerative effects were not so quickly shown nor were they so striking, there being no great reduction in number of mitoses observed after two hours and no complete disappearance of them before six hours in some individuals. In no case was there any recovery or recurrence of mitosis, but, rather, degeneration became greater with time, with very great disorganization of much of the nervous tissue before 20 hours. There was not only accumulation of disorganized material within the retina and central nervous system as reported by Strangeways and Fell (80), but within the tubes and cavities in other parts of the body as well, yet this did not appear in great quantity for four or six hours. There was extravasation of blood in embryos after two hours, and ever increasing with time after raying until in some specimens brain and retinal walls were folded and most of the mesenchymal spaces gorged. For the

pluripolar spindles, fragmentation of chromosomes and other abnormal mitoses of Strangeways and Fell (20) there were found tripolar spindles (figs. 10, 11), fragmented (figs. 13, 38) and dispersed chromosomes (figs. 13, 38) and in others condensed in a clump (figs. 31, 75, 76, 77), the last not being found by other workers.

Though different in method of exposure, the chicks being exposed to X-rays on successive days, yet the results obtained by Colwell, Gladstone, and Wakely were very similar to those reported in the present paper. In their paper of 1922, series I (24), the conclusion was reached that of those specimens which did develop after raying, all the organs and tissues which should develop during the period examined were differentiated, but were smaller in size. In series II and III (25) the same authors conclude that the effect is always destructive and is exerted chiefly on the ectoderm, neural tube and its associated structures, such as the retina and optic vesicle the epithelium of glandular structures, as the liver, or the mesonephros, and upon the red blood corpuscles. The effects consist in the detachment of the epithelium; diminution of the transparency of the cytoplasm, or the formation in the cytoplasm of minute granules or vacuoles; variation in degree of distinctness with which the chromosomes may be distinguished in the dividing nuclei, and in the staining reactions of the nuclei and cell bodies. The effect on the blood corpuscles appears also to be destructive. In a few cases a fibrinous clot appears in the heart or larger vessels. In their specimens receiving the full dosage, hemorrhages were frequent in the cavity of central nervous system and, to a less degree, other cavities of the body were partly filled with fibrinoid and cellular material. The cells in division after irradiation show chromosomes which are condensed into a clump. There appears to be no reduction in number of mitoses nor is there any stimulation.

The findings in the present paper present results similar to those reported by Colwell, Gladstone and Wakeley (25). There is less separation of the ectoderm and very little of the epitrichium. The effect upon the neural tissue and sense organs is as great as observed by these workers. In the more advanced stages after raying the results are probably much greater than they report. In only one situation do they report breaking of "internal limiting membrane lining the central canal of the cord and the canal partially filled with fibrinous-like deposit containing a group of small oval cells derived from the neuro-syncytium, forming the wall of the injured tube." Most specimens described in the present paper show exudations from

brain cells and often much debris within its cavity accompanied by definite spaces or fissures from which cells or cell-parts have come. The effect on the coats of the eye is much the same as that observed on the neural tissue. There is generally separation of the two coats within two hours, the distance increasing with time after raying. In nearly every case this space is filled with fibrinous-like material to which disorganized cells are added in a few hours, the total mass becoming so great as to cause folding of retinal coats. Both coats may be broken or fissured which may admit blood cells to the mass within the space. Within the lens vesicle disorganized material occurs after a few hours. Colwell, Gladstone and Wakeley (25) report no widespread modifications in the eye, reporting only on the distribution of pigment granules and staining qualities of the pigment cells. They report the effect of the X-rays on the entoderm and its derivatives as being very slight, while the present paper reports degenerative effects in all advanced stages. They report little or no effect in other tissues except blood.

It is in comparison of the blood and mitoses that the present paper agrees most closely with these workers. In both extensive hemorrhages are reported and in both destructive effects are noted. These effects are shown by both in the breaking up of cytoplasm (figs. 1, 2, 15), the formation of granules, the fragmentation of karyosomes (figs. 39, 42, 46), and occasionally the fragmentation of the whole cell (figs. 24, 70, 72). Both report cells without nuclei. (Figs. 6, 7.)

The appearance of the cells which are in division is reported much the same in both papers. Both report variation in degree of distinctness with which chromosomes may be distinguished in dividing nuclei. Both report the condensation of the chromosomes into clumps (figs. 31, 75, 76, 77) in which the individual elements could not be followed. It appears, then, that with lighter doses given at daily intervals cell division and cellular structure may be modified, but widespread destruction is not produced, while with single, heavy dosage, as reported in the present paper, modifications, similar to those reported by the workers above, appear, after a few hours, to be followed by even greater degeneration in later stages.

Several workers have employed Radium and others ultra-violet light in their experiments on living tissues. The effects of both of these are very similar to those produced by exposures to X-rays.

One very striking modification of living cells produced by X-rays, radium and ultra-violet light is the suppression of mitosis. In all

the embryos on which report is made in this paper, with the exception of one individual, whose susceptibility to the dosage of X-rays employed must have been lower than all the others, a very definite reduction in number of mitoses occurred in two hours with, in almost all cases, complete disappearance of all cell division in six hours. The individual variation that occurred was not great enough to be a matter of record. No reduction in number or other change could be observed in embryos twenty minutes after raying, but Strangeways and Fell (80) found a very rapid fall in thirty minutes. After the abrupt fall a further reduction continued much more gradually for three hours when there began a rise in number which continued to increase till the original number had been surpassed. Canti and Spear (23) recorded a similar sharp reduction, followed by a gradual rise which sometimes was equal to the fall for cells growing in vitro and exposed to gamma radiation. Grasnick (36) found the nuclei, especially those in mitosis, more affected by gamma rays while the cytoplasm was influenced more by the beta rays of radium.

Canti (21) demonstrated the effect of radium upon chick embryo tissues growing in vitro by making slow pictures of them. In this unique method are shown cells, which moving, cease mobility, become round and form bubbles in their process of breaking down. Mitosis is stopped in 20 minutes. Two daughter cells moving apart are stopped.

Canti and Donaldson (20) found similar stopping of mitoses by exposure to radium, the choroid tissue of chick embryos growing in vitro. In this it was observed that the more intense the irradiation the sooner was mitosis stopped.

Reiss (73) compares the action of X-rays and radium on the nucleus and cytoplasm in "Pour nos experiences, le rapport des sensibilites du cytoplasme et du noyau serait de 18 : 1 pour le radium, et de 3.8 : 1 pour les rayons X."

That ultra-violet light acts similarly to X-ray and radium is shown by Earl (31) who observed its action upon blood and fibroblasts. The erythrocytes became swollen and lost their hemoglobin; while white blood cells were fixed and coagulated. Fibroblasts from chick embryos were observed to swell, develop vacuoles and coagulate.

Hinricks (45, 46) has done extensive experimenting, using ultraviolet light upon chick embryos, and finds abnormalities and widespread modifications.

Short exposures of tissue cultures of fibroblasts to ultra-violet light was recorded by Kler (54) as having very little effect; to produce a lethal effect heavier doses being necessary. In a similar treatment of chick heart fragments after an exposure of 15 seconds to 2 minutes a stimulation of contraction was observed by Kler (55) who found for the intensity of light employed 2-3 hours exposure was necessary to be lethal. Watrin (89) exposed tadpoles in water to X-rays and to ultra-violet light, finding the former had no effect, but during exposure to the latter the tadpoles moved rapidly and after 3 doses at 5-day intervals they lost weight and pigment, and died in 5 days.

GENERAL CONCLUSIONS

The effects of irradiation with X-rays appear as destructive changes in all tissues, varying directly with the length of time after exposure.

These effects for the most part are general rather than local.

Effects make their appearance at about the same time after irradiation in all series.

Mitoses are not stopped suddenly, but a gradual diminution takes place until, after 4-6 hours, few or none occur. Some mitotic figures show chromosomes somewhat condensed into a clump so that individual elements cannot be discerned.

No acceleration of growth can be found.

The greatest effects are shown in the nerve tissue, sense organs, epithelium and blood cells.

Pronounced effects are shown in: Accumulation of disorganized material in vesicles, canals and cavities of body; detachment of epithelial membranes, limiting membranes, and separation of retinal walls; great hemorrhages into loose mesenchyme; appearance of granules in the cytoplasm; decrease in differentiation of nuclear structure.

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EXPLANATION OF PLATES

All the figures in plates LX to LXIII are drawings made in all cases with the aid of a camera lucida using a Leitz 16 × ocular and 95 × oil immersion objective. All drawings were made at a magnification of 2,800 diameters, and reduced to one-half in reproduction.

PLATE LX

FIG. 1. 28-45. Ectoderm showing vacuoles and fraying of outer wall.

FIG. 2. 28-45. Entoderm from open gut showing fraying of outer walls.

FIG. 3. 28-45. A mesodermal cell, very dense nucleus and many prominent, dark granules.

FIG. 4. 28-45. A mesenchymal cell with vacuolated nucleus.

A group of blood cells from 28-45:

FIG. 5. A large blood cell undergoing cytoplasmic fragmentation.

FIGS. 6 and 7. Degenerating cells without nuclei.

FIG. 8. Cells with two nuclei.

FIG. 9. Blood cells, one of which has no nucleus.

All are degenerated as shown by the granules within.

FIGS. 10 and 11. Cells with tripolar nuclei.

FIG. 12. A giant blood cell.

PLATE LX

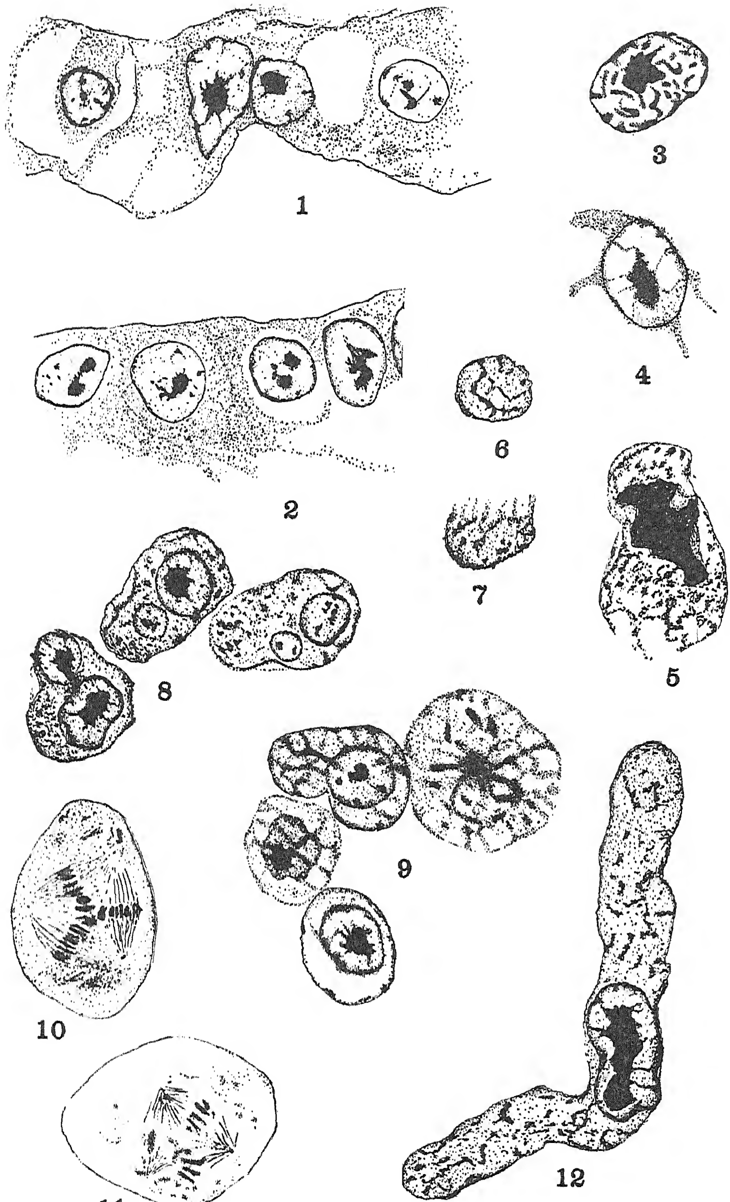

PLATE LXI

FIG. 13. 48-60. Entodermal cell with dispersed chromosomes.

FIG. 14. 48-54. Cells composing the urinary tubule showing numerous granules in the cytoplasm.

FIG. 15. 48-62. Cells from the auditory vesicle showing the frayed cytoplasm and fragmented karyosomes.

FIG. 16. 48-54. A blood cell with disarranged chromosomes.

FIG. 17. 48-54. Blood cell showing condensation of the chromosomes into a clump.

FIG. 18. 48-54. Blood cell with prominent granules and broken cellular wall.

FIG. 19. 48-54. Blood cell with clumped chromosomes somewhat disarranged and degenerating.

FIG. 20. 48-60. Blood cells with broken cell walls and oozing cytoplasm.

FIGS. 21 and 22. 48-60. Mesenchymal cells with somewhat shrunken cytoplasm.

FIGS. 23 and 24. 48-60. Blood cells undergoing degeneration and fragmentation.

PLATE LXI

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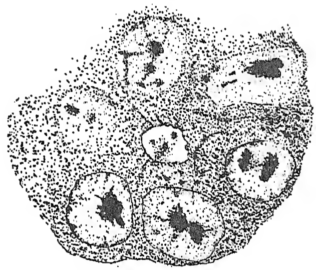

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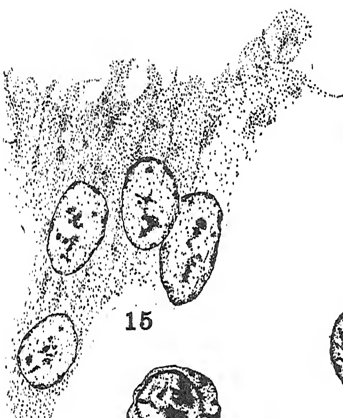

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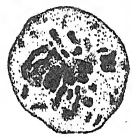

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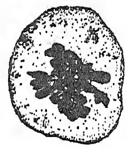

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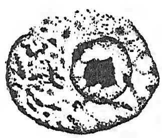

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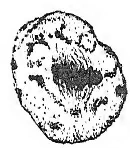

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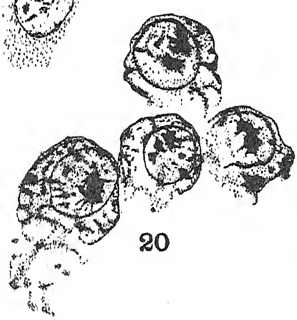

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PLATE LXII

FIG. 25. 60-64. A cell from the auditory vesicle showing slight clumping of chromosomes.

FIG. 26. 60-64. Cell from auditory vesicle with chromatin condensed into a tangled knot. Pycnosis.

FIGS. 29 and 34. 60-64. Cell from mid-gut showing a condensation of the chromosomes.

FIG. 30. 60-64. Cell from the auditory vesicle showing much vacuolated nucleus.

FIGS. 27, 31, 32, 33. 60-64. Blood cells with shrunken nuclei.

FIG. 28. 60-64. Blood cell with chromosomes disarranged suggesting pseudo-amitosis.

FIG. 36. 60-64. Blood cell with four nuclei.

FIG. 37. 60-64. Mesodermal cell with clumped chromosomes and granular cytoplasm.

FIG. 38. 60-64. Mesodermal cell with dispersed and fragmented chromosomes.

FIGS. 39, 40, 41, 42, 43, 44, 45. 60-66. Blood cells with prominent granules and more or less shrunken and degenerating.

FIG. 46. 60-66. Cells from the urinary tubule showing granular cytoplasm and fragmented karyosomes.

PLATE LXII

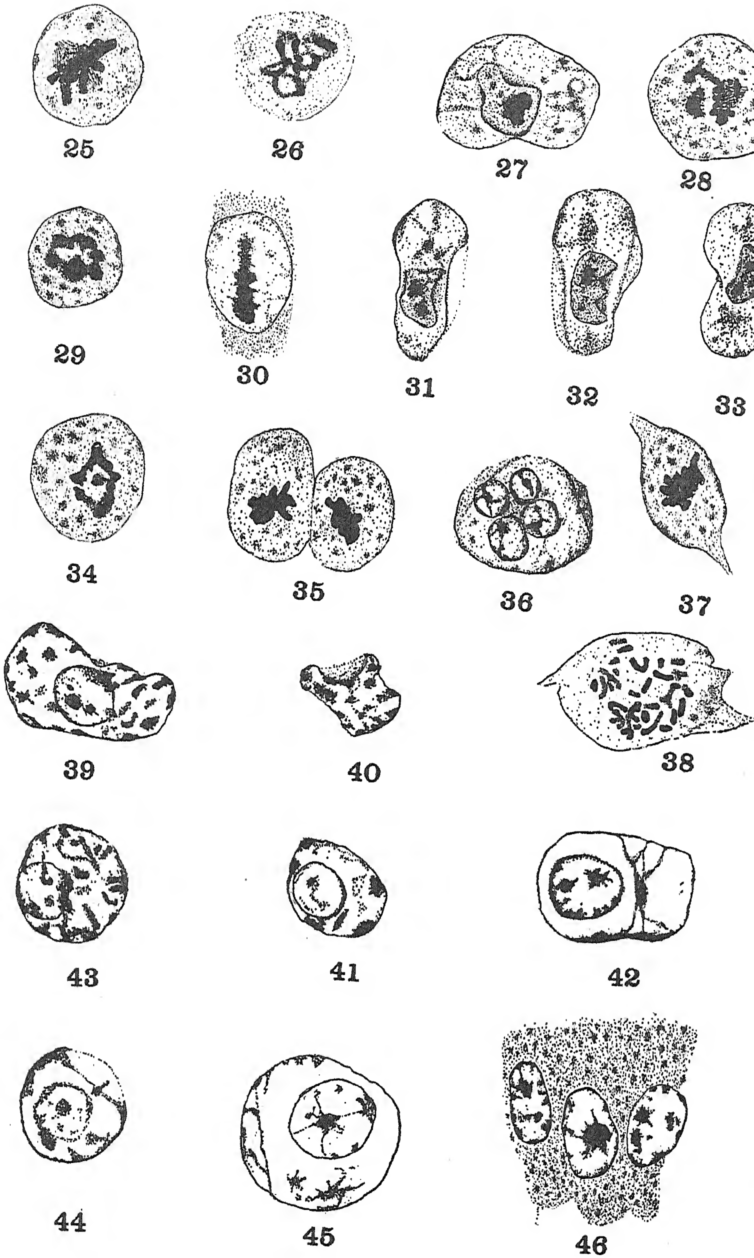


PLATE LXIII

FIGS. 47, 48. 75-94. Blood cells shrunken and degenerating.

FIG. 49. 75-94. Blood cell almost clear.

FIG. 50. 75-94. Blood cell with fragmented nucleus.

FIG. 51. 75-94. Blood cell which is stained very darkly.

FIGS. 52, 53. 75-78. Mesodermal cells whose nuclei are dividing by amitosis.

FIG. 54. 75-78. Mesodermal cell with fragmented nucleus.

FIGS. 55, 56, 57, 58, 59. 75-94. Blood cells with fragmented nuclei and granular cytoplasm.

FIGS. 61, 62. 75-78. Small blood cells.

FIG. 63. 75-78. Elongated cell from the neural tube, showing dispersed chromosomes.

FIGS. 64, 65, 66, 67, 74. 96-114. Blood cells much degenerated and almost clear.

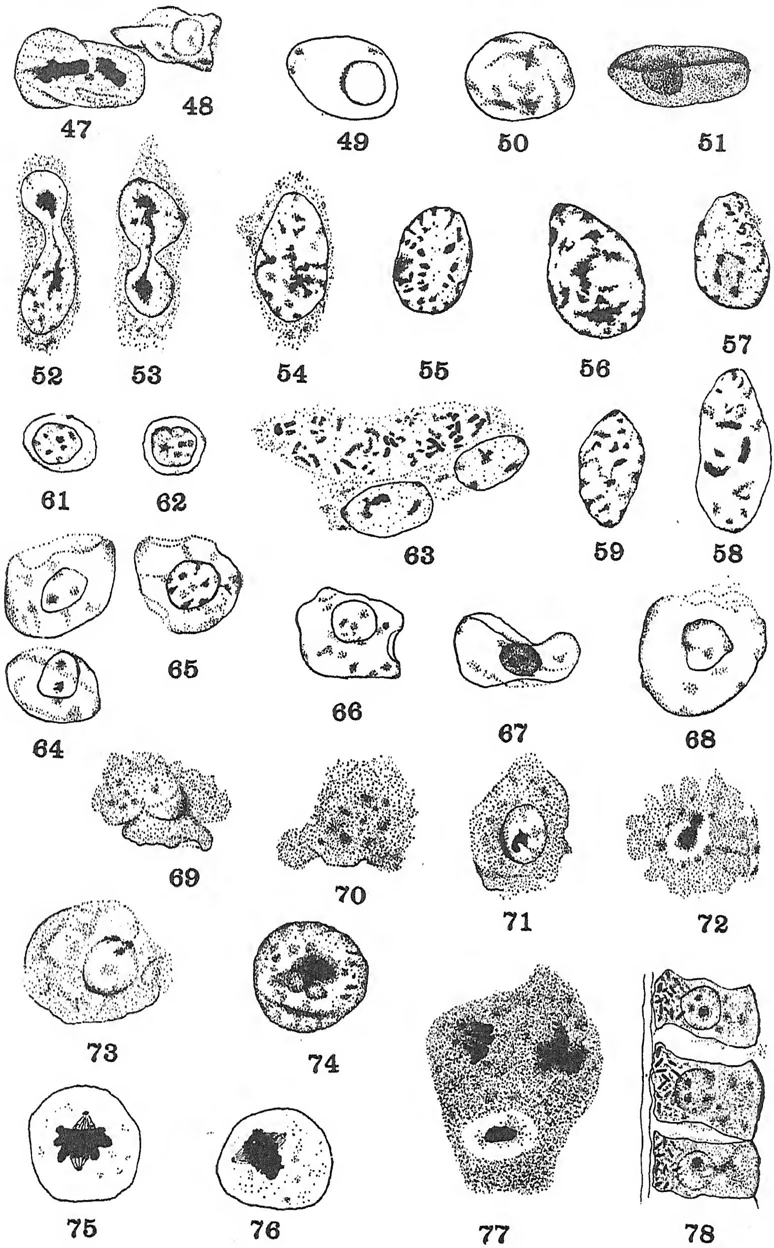
FIGS. 68, 69, 70, 71, 72, 73. 96-114. Blood cells which are degenerating and breaking up. Pseudopodium-like projections extend from the cytoplasm of several cells.

FIGS. 75. 76. 120-123. Cells from the brain showing clumping of the chromosomes.

FIG. 77. 120-123. Liver cells showing chromosome clump.

FIG. 78. 120-140. Shrunken Pigment cells from the retina.

PLATE LXIII



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